

## **Glossary derived from:**

Human Research Program Integrated Research Plan, Revision A, (January 2009). National Aeronautics and Space Administration, Johnson Space Center, Houston, Texas 77058, pages 232-280.

Report No. 153: Information Needed to Make Radiation Protection Recommendations for Space Missions Beyond Low-Earth Orbit (2006). National Council on Radiation Protection and Measurements, pages 309-318. Reprinted with permission of the National Council on Radiation Protection and Measurements, <http://NCRPonline.org>.

Managing Space Radiation Risk in the New Era of Space Exploration (2008). Committee on the Evaluation of Radiation Shielding for Space Exploration, National Research Council. National Academies Press, pages 111-118.

## **-A-**

**AAPM:** American Association of Physicists in Medicine.

**absolute risk:** Expression of excess risk due to exposure as the arithmetic difference between the risk among those exposed and that obtaining in the absence of exposure.

**absorbed dose (D):** Average amount of energy imparted by ionizing particles to a unit mass of irradiated material in a volume sufficiently small to disregard variations in the radiation field but sufficiently large to average over statistical fluctuations in energy deposition, and where energy imparted is the difference between energy entering the volume and energy leaving the volume. The same dose has different consequences depending on the type of radiation delivered. Unit: gray (Gy), equivalent to 1 J/kg.

**ACE:** Advanced Composition Explorer Mission, launched in 1997 and orbiting the L1 libration point to sample energetic particles arriving from the Sun and interstellar and galactic sources. It also provides continuous coverage of solar wind parameters and solar energetic particle intensities (space weather). When reporting space weather, it can provide an advance warning (about one hour) of geomagnetic storms that can overload power grids, disrupt communications on Earth, and present a hazard to astronauts. ([http://www.srl.caltech.edu/ACE/ace\\_mission.html](http://www.srl.caltech.edu/ACE/ace_mission.html))

**acute effects:** short-term biological effects of exposure to radiation, including headaches, dizziness, nausea, and illness that can range from mild to fatal.

**acute exposure:** Radiation exposure of short duration.

**AGS:** Alternating Gradient Synchrotron (at Brookhaven National Laboratory).

**ALARA (As Low As Reasonably Achievable):** An essential operational safety requirement, as well as a regulatory requirement, that emphasizes keeping exposure to radiation as low as possible using reasonable methods, and not treating dose limits as “tolerance values”; defined at NASA as limiting radiation exposure to a level that will result in an estimated risk below the limit of the 95 percent confidence level.

**albedo:** secondary radiation produced by interactions of galactic cosmic rays and high-energy solar protons with matter in the atmosphere or on the surface.

**ALL:** acute lymphocytic leukemia.

**alpha particle:** An energetic charged nucleus consisting of two protons and two neutrons. This particle is identical to the  ${}^4_2\text{He}$  nucleus.

**ALTEA:** Anomalous Long-Term Effects in Astronauts study  
([http://www.nasa.gov/mission\\_pages/station/science/experiments/ALTEA.html](http://www.nasa.gov/mission_pages/station/science/experiments/ALTEA.html))

**AM:** amplitude modulation.

**AMA:** American Medical Association.

**AMAC:** American Medical Advisory Committee.

**AML:** acute myelogenous leukemia.

**Amu:** atomic mass unit (ALSO : u).

**ANLL:** acute nonlymphocytic leukemia.

**annual risk:** The risk in a given year from an earlier exposure. The annual risk (average) from an exposure is the lifetime risk divided by the number of years of expression.

**ANP:** atrial natriuretic peptide.

**ANS:** American Nuclear Society.

**ANSI:** American National Standards Institute.

**ApoE4:** Apolipoprotein E isoform 4. Modification of Apo4 is major risk factor in Alzheimer's disease.

**apoptosis:** A specific mode of cell death (also known as programmed cell death) that can be triggered by exposure to radiation, especially in cells of lymphoid/myeloid or epithelial lineage. Extensive apoptosis contributes to the hematopoietic and gastrointestinal symptoms seen in acute radiation syndrome.

**ARC:** NASA Ames Research Center.

**Ares V/Heavy Lift Launch Vehicle:** a NASA vehicle intended to deliver cargo from Earth to low Earth orbit.

**ARM:** Atmospheric Radiation Measurements.

**ascent stage:** The pressurized upper stage of the Lunar Lander in which the crew pilots the lander from lunar orbit to the lunar surface and return. The ascent stage takes off from the

descent stage, leaving the latter behind on the surface.

**AT:** ataxia telangiectasia.

**ATM:** ataxia telangiectasia mutated.

**AU:** approximately the mean distance between the Earth and the Sun. (149,597,870.691 kilometers)

**AX-2:** NASA Ames Research Center Experimental Suit 2, designed during the Apollo program as a lunar surface hard suit to bend at the waist and rotate in the torso so that the crew member can reach down to the ground with one hand. Fabricated from fiberglass.

**AX-5:** NASA Ames Research Center Experimental Suit 5, designed during the Space Station Advanced Development program to provide a durable hard suit for extended operations in zero gravity. Fabricated from numerically milled aluminum forgings.

## **-B-**

**background radiation:** The amount of radiation to which a member of the population is exposed from natural sources, such as terrestrial radiation from naturally-occurring radionuclides in the soil, cosmic radiation originating in outer space, and naturally-occurring radionuclides deposited in the human body. The natural background radiation received by an individual depends on geographic location and living habits. In the United States, the background radiation is on the order of 1 mSv y<sup>-1</sup>, excluding indoor radon which amounts to ~2 mSv/year on average.

**BAF:** Booster Applications Facility (the name used to designate the NSRL during planning and construction phases).

**BaRyon:** Quark bound state with zero strangeness.

**BCC:** basal cell carcinoma.

**BCD:** budget change directive.

**BEIR:** Biological Effects of Ionizing Radiation. One of a series of reports on the health risks from exposure to low levels of ionizing radiation issued by the Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, Board on Radiation Effects, Research Division on Earth and Life Studies, National Research Council of the National Academies of Science of the United States, referred to by a Roman number denoting its position in the sequence of reports. At the time of this writing, the latest report is BEIR VII.

**BEVALAC:** An accelerator system at Lawrence Berkeley National Laboratory consisting of the Bevatron (an early, high-energy synchrotron accelerator constructed in the 1950s and used to discover the antiproton), accelerating particles delivered by the SuperHILAC (first built as the HILAC - Heavy Ion Linear Accelerator - in 1957; along with a similar one at Yale University, the first machine in the US built specifically to accelerate heavy ions, completely rebuilt into the SuperHILAC in 1971). Closed in 1993.

**biological end point:** effect or response being assessed, e.g., cancer, cataracts.

**bipolar device:** a type of semiconductor whose operation is based on both majority and minority carriers.

**BNL:** Brookhaven National Laboratory in Upton (Long Island), New York.

**BRCA1:** breast cancer 1 tumor suppressor gene.

**BRCA2:** breast cancer 2 tumor suppressor gene.

**BrdU:** bromodeoxyuridine.

**BRYNTRN:** BaRYoN TRaNsport code, a computer code for simulating baryon transport.

**-C-**

**CAD:** computer aided design.

**CaLV:** Cargo Launch Vehicle.

**CAM:** computerized anatomical man model.

**carbon composite:** a composite incorporating carbon and other materials for use in lightweight structures, strong enough to substitute for aluminum and other metals in the construction of many parts of a spacecraft, notably the pressure vessel shell. It may incorporate boron, epoxy, polyethylene, hydrogen, or other materials that enhance radiation shielding properties.

**cargo habitat:** a crew habitat that the Lunar Lander carries for delivery to the Lunar Outpost as a key part of the “Outpost-first” strategy considered by NASA as part of the Space Exploration Initiative program.

**CB:** Control Board.

**CDC:** Center for Disease Control and Prevention.

**CEDE:** committed effective dose equivalent.

**CENELEC:** European Committee for Electrotechnical Standardization.

**CERN:** European Organization for Nuclear Research.

**CEV:** Crew Exploration Vehicle.

**CFR:** Code of Federal Regulations.

**CHMO:** Chief Health And Medical Officer (NASA).

**chronic effects:** long-lasting effects of exposure to radiation; includes cancer, cataracts, and nervous system damage.

**chronic exposure:** Radiation exposure over long times (continuous or fractionated).

**CI:** confidence interval.

**CL:** confidence level.

**CLV:** Crew Launch Vehicle.

**CME:** coronal mass ejection, an explosion of plasma released from the atmosphere (or corona) of the Sun.

**CML:** chronic myelogenous leukemia.

**CNP:** cyclic nucleotide phosphatase.

**CNS:** central nervous system.

**Composites:** materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure.

**computerized anatomical male/female:** a model of human geometry used to evaluate radiation doses at various points inside the body.

**Constellation system:** the complete ensemble of launch vehicles, flight vehicles, ground support, support services, and lunar and planetary surface systems associated with the Vision for Space Exploration initiated during the Bush administration.

**coronal mass ejection (CME):** A transient outflow of plasma from or through the solar corona which may be associated with the generation of solar-particle events.

**cosmic-ray modulation:** The variation of the observed cosmic-ray intensity as a function of the solar cycle. The cosmic-ray intensity within the solar system is observed to vary approximately inversely with the solar activity cycle that controls the interplanetary magnetic field.

**COTS:** commercial, off-the-shelf.

**CPD:** crew passive dosimeter.

**CPU:** central processor unit.

**CRaTER:** Cosmic Ray Telescope for the Effects of Radiation.

**CRCPD:** Conference of Radiation Control Program Directors.

**CREME96:** Cosmic Ray Effects on Micro-Electronics (1996 revision), a computer code.

**cross section ( $\sigma$ ):** probability per unit particle fluence of a given end point. Unit: cm<sup>2</sup>.

**CT:** computed tomography.

**CTA:** conditioned taste aversion.

**CVD:** cardiovascular disease.

**CW:** continuous wave.

**CxP:** Constellation Program.

## **-D-**

**D<sub>r</sub>:** dose-rate (Gy/hr).

**DAAC:** Distributed Active Archive Center.

**DDREF:** dose and dose-rate effectiveness factor (the degree to which both dose and dose rate may influence the biological effects of exposure to a given dose of radiation).

**delta rays:** Electrons directly ejected from atoms in matter by radiation.

**descent stage:** The lower stage of the Lunar Lander that includes the descent and landing engines and propellant tanks to serve them. The crew ascending back to lunar orbit in the ascent stage leaves the descent stage behind on the lunar surface.

**descent stage habitat:** in the descent stage, a pressurized crew habitat in which the crew would live during sortie missions.

**deterministic process:** process whereby a given event will occur whenever its dose threshold is exceeded.

**deterministic effects:** early radiation effects usually related to a significant fraction of cell loss, exceeding the threshold for impairment of function in a tissue; so called because the statistical fluctuations in the number of affected cells are very small compared to the number of cells required to reach the threshold (ICRP 1991), above which the severity varies with dose.

**detriment:** Health detriment is the sum of the probabilities of all the components of health effects. These include in addition to fatal cancer the probability of heritable effects and the probability of morbidity from nonfatal cancer.

**DHS:** Department of Homeland Security.

**DNA:** deoxyribonucleic acid.

**DOD:** Department of Defense.

**DOE:** Department of Energy.

**dose:** A general term used when the context is not specific to a particular dose quantity. When the context is specific, the name or symbol for the quantity is used [*i.e.*, absorbed dose ( $D$ ), mean absorbed dose ( $DT$ ), dose equivalent ( $H$ ), effective dose ( $E$ ), equivalent dose ( $HT$ ), or organ dose equivalent].

**dose equivalent (H):** Estimate of radiation risk that accounts for differences in the biological effectiveness of different types of charged particles that produce the absorbed dose.  $H=Q \times D$ , where  $Q$  is a quality factor based on the type of radiation ( $Q = 1$  for x-rays). NASA uses  $Q$  as specified in ICRP Publication 60 (ICRP, 1991). Unit: sievert (Sv), equivalent to 1 J/kg.

**dose limit:** A limit on radiation dose that is applied by restricting exposure to individuals or groups of individuals in order to prevent the occurrence of radiation-induced deterministic effects or to limit the probability of radiation related stochastic effects to an acceptable level. For astronauts working in low-Earth orbit, unique dose limits for deterministic and stochastic effects have been recommended by NCRP.

**dose rate:** Dose delivered per unit time. Can refer to any dose quantity (*e.g.*, absorbed dose, dose equivalent).

**dose-response model:** A mathematical formulation of the way in which the effect, or response, depends on dose.

**dosimeter:** A radiation detection device worn or carried by an individual to monitor the individual's radiation exposure. For space activities, a device worn or carried by an astronaut in-flight.

**DREF:** dose rate effectiveness factor (the degree to which dose rate may influence the biological effects of exposure to a given dose of radiation).

**DRM:** Design Reference Mission.

**DSB:** double strand break.

**DTRA:** Defense Threat Reduction Agency.

**-E-**

**E:** effective dose/ energy.

**EAR:** excess additive risk (cf. absolute risk).

**ED50:** dose to cause 50 % of the population to have the effect (*e.g.*, nausea).

**EDS:** Earth departure stage.

**EEG:** electroencephalogram.

**effective dose (E):** The sum over specified tissues of the products of the equivalent dose in a tissue ( $H_T$ ) and the tissue weighting factor for that tissue or organ ( $w_T$ ) (*i.e.*,  $E = w_T H_T$ ). Effective dose ( $E$ ) applies only to stochastic effects. Unit: sievert (Sv), equivalent to 1 J/kg.

**electron volt (eV):** a unit of energy equivalent to  $1.602 \times 10^{-19}$  joules.

**ELF:** extremely low frequency.

**ELR:** excess lifetime risk.

**EMF:** electromagnetic field.

**EML:** Environmental Measurements Laboratory, New York, NY.

**EMS:** emergency medical services.

**EMU:** Extravehicular mobility unit, the space suit developed for space shuttle crews that also serves on the ISS. The EMU features a hard upper torso and soft lower torso, arms, and legs over the pressure bladder. The entire EMU except the helmets and boots is covered by the thermal micrometeoroid garment.

**electron volt (eV):** A unit of energy =  $1.6 \times 10^{-12}$  ergs =  $1.6 \times 10^{-19}$  J; 1 eV is equivalent to the energy gained by an electron in passing through a potential difference of 1 V; 1 keV = 1,000 eV; 1 MeV = 1,000,000 eV.

**EOS:** Earth Observing System.

**EPA:** Environmental Protection Agency.

**equivalent dose ( $H_T$ ):** The product of the mean absorbed dose in an organ or tissue and the radiation weighting factor ( $w_R$ ) of the radiation type of interest. For external exposure  $w_R$  applies to the radiation type incident on the body.

**ERR:** excess relative risk.

**erythema:** A redness of the skin.

**ESA:** European Space Agency.

**ESMD:** Exploration Systems Mission Directorate (NASA).

**ESP:** energetic storm particle.

**ESTEC:** European Space Research and Technology Centre.

**excess relative risk (ERR):** The ratio between the total risk, including the increase due to radiation exposure, and the baseline risk in the absence of radiation exposure; if the excess equals the baseline the relative risk is two.

**exposure (technical use):** A measure of the ionization produced in air by x or gamma radiation. Exposure is the sum of electric charges on all ions of one sign produced in air when all electrons liberated by photons in a volume of air are completely stopped, divided by the mass of the air in the volume. The unit of exposure in air is the roentgen (R) or in SI units it is expressed in coulombs (C),  $1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}$ .

**exposure (non-technical use):** the presentation of an individual or material to radiation likely to deliver a significant dose over a period of time.

**EVA:** extravehicular activity.

**excess risk:** the increase in the probability of a certain effect on an individual who has been exposed to a given dose of radiation over the probability of that effect in the absence of radiation exposure.

**extravehicular activity:** Any activity undertaken by the crew outside a space vehicle or habitat.

**-F-**

**favorable propagation path:** A concept suggesting that the Archimedean spiral path from the earth to the sun would connect to a specific solar longitude. It is based on the concept that charged particles travel along the interplanetary magnetic field which is transported out from the sun. For an idealized constant speed solar wind flow, if the interplanetary magnetic field is frozen in the plasma, then the result would form an Archimedean spiral.

**FEMA:** Federal Emergency Management Agency.

**FIRE:** First ISCCP Regional Experiment.

**first ionization potential:** The energy required to remove the least bound electron from an electrically neutral atom. (The ionization potential is usually given in electron volts.)

**FISH:** fluorescence *in situ* hybridization.

**fluence: (1) ICRU definition ( $\Phi$ ):** The quotient of  $dN$  by  $da$ , where  $dN$  is the number of particles incident on a sphere of cross-sectional area  $da$  (*i.e.*,  $\Phi = dN/da$ ). The unit for fluence is  $1/\text{m}^2$ , but  $\text{cm}^{-2}$  is frequently used; (fluence may be a function of one or more other variables [*e.g.*,  $\Phi(L, t)$ , the distribution of fluence as a function of linear energy transfer ( $L$ ) and time ( $t$ ]). (2) planar fluence ( $F$ ): The net number of charged particles traversing a given area. Unit: particles/ $\text{cm}^2$ .

**fluence rate ( $dF/dt$ ):** Change in fluence over a given small time interval, or the time derivative of the fluence. Unit:  $1/\text{m}^2 \text{ s}$ .

**FLUKA:** a general purpose Monte-Carlo computer code for calculations of particle transport and interactions with matter (<http://www.fluka.org/>).

**flux ( $\Phi$ ):** Term used historically by the nuclear community for fluence rate and also used for particle flux density, but deprecated by the ICRU convention to eliminate confusion between the terms "particle flux density" and "radiant flux." See *fluence rate*.

**FM:** frequency modulation.

**FR:** fixed-ratio.

**fractionation:** The delivery of a given total dose of radiation as several smaller doses, separated by intervals of time.

**FSP:** fission surface power.

**FY:** Fiscal Year.

## **-G-**

**galactic cosmic rays:** the components of galactic cosmic radiation.

**galactic cosmic radiation (GCR):** The charged-particle radiation outside the Earth magnetosphere comprised of 2 % electrons and positrons, and 98 % nuclei, the latter component consisting (by fluence) of 87 % protons, 12 % helium ions, and 1 % high atomic number, high-energy (HZE) particles.

**gamma rays:** Short-wavelength electromagnetic radiation of nuclear origin (approximate range of energy: 10 keV to 9 MeV).

**GCR:** galactic cosmic radiation/ galactic cosmic rays.

**GCR:** galactic cosmic radiation.

**GEANT:** A computer application for the simulation of the passage of particles through matter including detector description and simulation. (<http://geant4.cern.ch/>)

**GEO:** Geostationary or Geosynchronous Earth Orbit.

**Geostationary Operational Environmental Satellite (GOES):** A satellite in geosynchronous orbit used for monitoring protons. The satellite travel at the same angular speed above the equator as Earth's rotation and therefore appears stationary when observed from Earth's surface.

**GGTP:** gamma-glutamyl transpeptidase.

**GI:** gastrointestinal.

**GLE:** ground level event.

**GM:** geometric mean.

**GPM:** Global Precipitation Measurement.

**gray (Gy):** The International System (SI) unit of absorbed dose of radiation, 1 Gy = 1 J kg<sup>-1</sup>.

**gray equivalent** ( $G_T$  or Gy-Eq): The product of  $D_T$  and  $R_i$ , where  $D_T$  is the mean absorbed dose in an organ or tissue and  $R_i$  is a recommended value for relative biological effectiveness for deterministic effects for a given particle type  $i$  incident on the body ( $G_T = R_i \times D_T$ ). The SI unit is J/kg (NCRP, 2000).

**GSD**: geometric standard deviation (the standard deviation of the logarithms of a set of random variables, for which the geometric mean is the square root of their product).

**GSi**(Gesellschaft für Schwerionenforschung): Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany.

**GSM**: global system for mobile communications.

**$G_T$** : gray equivalent.

## **-H-**

**HACD**: Human Adaptation and Countermeasures Division.

**HDPE**: high-density polyethylene, defined as having a density greater than  $0.94 \text{ g/cm}^3$ .

**heavy charged particles**: Atomic and subatomic charged particles with masses substantially heavier than that of an electron.

**heavy ions**: Nuclei of elements heavier than helium such as nitrogen, carbon, boron, neon, argon or iron which are positively charged due to some or all of the atomic electrons having been stripped from them.

**HEDS**: Human Exploration and Development of Space.

**HEFD**: Habitability and Environmental Factors Division.

**heliocentric**: A measurement system with its origin at the center of the sun.

**heliolongitude**: Imaginary lines of longitude on the sun measured east (left) or west (right) of the central meridian (imaginary north-south line through the middle of the visible solar disk) as viewed from Earth. The left edge of the solar disk is  $90^\circ\text{E}$  and the right edge is  $90^\circ\text{W}$ .

**heliosphere**: The magnetic bubble containing the solar system, solar wind, and entire solar magnetic field. It extends beyond the orbit of Pluto.

**HEPAD**: High Energy Proton and Alpha Detector.

**high atomic number, high-energy (HZE) particles**: Heavy ions having an atomic number greater than that of helium (such as nitrogen, carbon, boron, neon, argon or iron ions that are positively charged) and having high kinetic energy.

**high-LET:** Radiation having a high-linear energy transfer; for example, protons, alpha particles, heavy ions, and interaction products of fast neutrons.

**HIMAC:** Heavy Ion Medical Accelerator, Chiba Japan.

**HMF:** heliospheric magnetic field.

**HPC:** Hydrological Process and Climate.

**HPRT:** hypoxanthine-guanine phosphoribosyl transferase.

**HQ:** Headquarters.

**HRP:** Human Research Program.

**HRP CB:** Human Research Program Control Board.

**H<sub>T</sub>:** equivalent dose.

**HZE:** high atomic number and energy.

**HZETRN:** a transport code developed specifically for high-charge, high-energy particles that is widely used for space radiation shielding and design calculations.

**HZE:** high atomic number, high energy/ highly energetic, heavy, charged particles.

**-I-**

**IACUC:** Institutional Animal Care and Use Committee.

**IAEA:** International Atomic Energy Agency.

**ICNIRP:** International Commission on Non-Ionizing Radiation Protection.

**ICRP:** International Commission on Radiation Protection.

**ICRU:** International Commission on Radiation Units and Measurements.

**IDIQ:** Indefinite delivery/indefinite quantity.

**IEEE:** Institute of Electrical and Electronics engineers.

**IL-2:** interleukin-2.

**IL-6:** interleukin-6.

**incidence:** The rate of occurrence of a disease, usually expressed in number of cases per million.

**IND:** improvised (or otherwise acquired) nuclear device.

**interplanetary magnetic field:** The magnetic field in interplanetary space. The interplanetary magnetic field is transported out from the sun via the solar wind.

**interplanetary shocks:** An abrupt change in the velocity or density of charged particles moving faster than the wave propagation speed in interplanetary space, so that higher velocity components bunch into lower velocity components before these can get out of the way.

**ionizing radiation:** Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

**ionization:** The process by which a neutral atom or molecule acquires a positive or negative charge through the loss or gain of one or more orbital electrons.

**IPT:** Integrated Product Team.

**IRMA:** Integrated Risk Management Application.

**ISCCP:** International Satellite Cloud Climatology Project.

**ISS:** International Space Station.

**ISSMP:** ISS Medical Project.

**ITA:** Internal Task Agreement.

**IV & V:** Independent Validation & Verification.

**IWG:** Investigator Working Group.

**IWS:** Investigator Workshop.

**-J-**

**JSC:** NASA Johnson Space Center.

**JWST:** James Webb Space Telescope.

**-K-**

**kerma:** (an acronym for “Kinetic energy released in materials;” the sum of the initial kinetic energies for all charged particles released by uncharged ionizing radiation in a small sample of material divided by the mass of the sample. Kerma is the same as dose when charged particle equilibrium exists (i.e., when, on the average, the number of charged particles leaving the sample is compensated by an equal number of charged particles entering the sample).

**-L-**

**LAP:** latency associated peptide.

**LAR:** lifetime attributable risk.

**LaRC:** NASA Langley Research Center.

**LAT:** Lunar Architecture Team.

**latchup:** an anomalous state in a semiconductor in which the device no longer responds to input signals.

**latent period:** Period or state of seeming inactivity between time of exposure of tissue to an injurious agent and an observed response (also time to response or induction period).

**LBNL:** Lawrence Berkeley National Laboratory.

**LCD:** liquid crystal display.

**LCVG:** liquid cooling and ventilation garment.

**LDEF:** Long Duration Exposure Facility.

**LDL:** low-density lipoproteins.

**LEND:** Low Energy Neutron Detector.

**LEO (low Earth orbit):** the environment in which most recent space missions have been concentrated, where the magnetic field of Earth provides protection against much of the radiation that would be encountered on more distant exploration missions, approximately 300 to 600 mile orbit radius.

**LET (linear energy transfer):** Measure of the average local energy deposition per unit length of distance traveled by a charged particle in a material. Unit: keV/ $\mu\text{m}$ .

**lifetime risk:** The lifetime probability of suffering from the consequences of a specific health effect. The total risk in a lifetime resulting from an exposure(s) is equal to the average annual risk times the period of expression.

**light ions:** Nuclei of hydrogen and helium which are positively charged due to some or all of the planetary electrons having been stripped from them.

**lineal energy ( $y$ ):** The quotient of  $\epsilon$  by  $\bar{l}$ , where  $\epsilon$  is the energy imparted to the matter in a given volume by a single (energy deposition) event and  $\bar{l}$  is the mean chord length of that volume (*i.e.*,  $y = \epsilon / \bar{l}$ ). The unit for lineal energy is J/m, but keV/ $\mu\text{m}$  is often used in practice ( $1 \text{ keV}/\mu\text{m} \sim 1.6 \times 10^{-10} \text{ J/m}$ ).

**linear energy transfer (LET):** Average amount of energy lost per unit of particle track length as an ionizing particle travels through material, related to the microscopic density distribution of energy deposited in the material and, therefore, a major characteristic of radiation leading to

different effects for the same dose of ionizing radiation of different LET on biological specimens or electronic devices.

**linear-quadratic model (also linear-quadratic dose-response relationship):** expresses the incidence of (e.g., mutation or cancer) as partly directly proportional to the dose (linear term) and partly proportional to the square of the dose (quadratic term).

**LIS:** local interstellar energy spectrum.

**LIS:** local interstellar GCR spectrum.

**LIS:** Local interplanetary Spectra.

**LLD:** lower limit of detection.

**LLU:** Loma Linda University.

**LLO:** low lunar orbit.

**lognormal:** If the logarithms of a set of values are distributed according to a normal distribution the values are said to have a lognormal distribution, or be distributed log normally.

**low-LET:** Radiation having a low-linear energy transfer; for example, electrons, x rays, and gamma rays.

**LRV:** Lunar Roving Vehicle.

**LSAC:** Life Sciences Applications Advisory Committee.

**LSS:** Life Span Study.

**LSS:** Life-Span Study of the Japanese atomic-bomb survivors.

**Lunar Lander:** the Constellation system vehicle that will travel between the Orion and the surface of the Moon.

**LWS:** Living With a Star (a NASA program).

## **-M-**

**MARIE:** Mars Radiation Environment Experiment.

**mass stopping power:** (see *stopping power*).

**MAT:** Mars Architecture Team.

**MCNPX:** Monte Carlo N-Particle eXtended.

**MDO:** Multi-disciplinary Optimization.

**mean absorbed (tissue) dose ( $D_T$ ):** The mean absorbed dose in an organ or tissue, obtained by integrating or averaging absorbed doses at points in the organ or tissue.

**mean-free path:** The average distance between particle collisions with nuclei, atoms or molecules in a material. Also, the average distance between scattering events in interplanetary particle propagation.

**MEEP:** Mir Environment Effects Payload.

**MEO:** Medium Earth Orbit.

**mFISH:** Multiplex Fluorescence *In Situ* Hybridization.

**Mir:** The Russian (previously Soviet) orbital space station.

**MISSE:** Materials on International Space Station Experiment.

**MML:** mouse myelogenous leukemia.

**MMOP:** Multilateral Medical Operations Panel.

**MOA:** Memorandum of Agreement.

**MODIS:** Moderate Resolution Imaging Spectrometer.

**MORD:** Medical Operations Requirements Documents.

**MOU:** Memorandum of Understanding.

**Mrem:** millirem.

**MRI:** magnetic resonance imaging.

**mSv:** millisievert.

**-N-**

**N:** nucleon.

**NAR:** Non-Advocate Review.

**NAS:** National Academy of Sciences.

**NASA:** National Aeronautics and Space Administration.

**NCI:** National Cancer Institute.

**NCRP:** National Council on Radiation Protection and Measurements.

**neutrons:** Particles with a mass similar to that of a proton, but with no electrical charge. Because they are electrically neutral, they cannot be accelerated in an electrical field.

**NIEL:** Non-ionizing energy loss, also called displacement kerma. The total kerma can be divided into an ionizing component and a displacement, or NIEL, component.

**NIH:** National Institutes of Health.

**NM:** neutron monitor.

**NOAA:** National Oceanic and Atmospheric Administration.

**noncancer:** Health effects other than cancer (*e.g.*, cataracts, cardiovascular disease) that occur in the exposed individual.

**Nowcasting:** prediction of total doses and the future temporal evolution of the dose once a solar particle event has begun.

**NOVICE:** Radiation Transport/Shielding Code.

**NPR:** NASA Procedural Requirements.

**NRA:** NASA Research Announcement.

**NRC:** National Research Council.

**NRC:** Nuclear Regulatory Commission (US).

**NSBRI:** National Space Biomedical Research Institute.

**NSCOR:** NASA Specialized Center of Research.

**NSF:** National Science Foundation.

**NSRL:** NASA Space Radiation Laboratory (at BNL).

**NTE:** Non-Targeted Effects.

**-O-**

**OBPR:** Office of Biological and Physical Research.

**OCHMO:** Office of Chief Health and Medical Officer.

**organ dose equivalent (  $DE_T$  ):** The mean dose equivalent for an organ or tissue, obtained by integrating or averaging dose equivalents at points in the organ or tissue. It is the practice in the space radiation protection community to obtain point values of absorbed dose ( $D$ ) and dose equivalent ( $H$ ) using the accepted quality factor-LET relationship [ $Q(L)$ ], and then to average the

point quantities over the organ or tissue of interest by means of computational models to obtain the organ dose equivalent ( $DE_T$ ). For space radiations, NCRP adopted the organ dose equivalent as an acceptable approximation for equivalent dose ( $H_T$ ) for stochastic effects.

**Orion Crew Exploration Vehicle:** The Constellation system vehicle that will carry passengers in low Earth orbit, or from low Earth orbit to the Moon or Mars, and then back to Earth. Often referred to as CEV; in this report referred to as the Orion crew module.

**OSHA:** Occupational Safety and Health Administration.

**-P-**

**PC:** Probability of Causation.

**PCC:** premature chromosome condensation.

**PCS:** personal communication system.

**PDF:** probability density function.

**PDF:** probability distribution function.

**PE:** Project Executive.

**PEL (permissible exposure limit):** Maximum amount of radiation to which an astronaut may be exposed. For terrestrial workers, PELs are legal limits, defined by OSHA. NASA PELs are set by the chief health and medical officer.

**PET:** positron emission tomography.

**photosphere:** The portion of the sun visible in white light. Also the limit of seeing down through the solar atmosphere in white light.

**PI:** Principal Investigator.

**PLR:** pressurized lunar rover.

**PLSS:** personal life support system.

**PM:** Project Manager.

**PP:** Project Plan.

**PPBE:** Planning, Programming, Budgeting and Execution.

**PPS:** proton prediction system/ pulses per second.

**PRD:** Passive Radiation Detector; Program Requirements Document.

**prevalence:** The number of cases of a disease in existence at a given time per unit of population, usually per 100,000 persons.

**protons:** The nucleus of the hydrogen atom. Protons are positively charged.

**protraction:** Extending the length of exposure, for example, the continuous delivery of a radiation dose over a longer period of time.

**PS:** Project Scientist.

**PSD:** Position-Sensitive Detector; also, Pulse Shape Discrimination.

**PVAMU:** Prairie View A&M University.

**PW:** pulsed wave.

**-Q-**

**Q:** quality factor.

**Q(L):** quality factor as a function of linear energy transfer.

**Q<sub>leukemia</sub>:** quality factor for estimating leukemia risks.

**Q<sub>solid</sub>:** quality factor for estimating solid cancer risks.

**QMSFRG:** quantum multiple scattering fragmentation model.

**quality factor (Q):** The factor by which absorbed dose ( $D$ ) at a point is modified to obtain the dose equivalent ( $H$ ) at the point (*i.e.*,  $H = Q D$ ), in order to express the effectiveness of an absorbed dose (in inducing stochastic effects) on a common scale of risk for all types of ionizing radiation. There is a specified dependence [ $Q(L)$ ] of the quality factor ( $Q$ ) as a function of the unrestricted linear energy transfer ( $L$ ) in water at the point of interest.

**quasithreshold dose:** The dose at which the extrapolated straight portion of the dose-response curve intercepts the dose axis at unity survival fraction.

**-R-**

**RAD:** Radiation Assessment Detector.

**RAM:** Radiation Area Monitor.

**radiation:** 1. The emission and propagation of energy through space or through matter in the form of waves, such as electromagnetic, sound, or elastic waves; 2. The energy propagated through space or through matter as waves; radiation or radiant energy, when unqualified, usually refers to electromagnetic radiation; commonly classified by frequency— Hertzian, infrared, visible, ultraviolet, x and gamma rays; 3. Corpuscular emission, such as alpha and beta particles, or rays of mixed or unknown type, such as cosmic radiation.

**radiation quality:** A general term referring to the microscopic distribution of the energy absorbed to yield a given total dose. For example, at resolutions of a few micrometers ionizing events will be more uniformly dispersed for gamma-ray radiation than for the neutron radiation, producing quantitatively different biological effects (see *relative biological effectiveness*).

**radiation weighting factor ( $w_R$ ):** A factor related to the relative biological effectiveness of different radiations in the calculation of equivalent dose ( $H_T$ ) (see *equivalent dose*), independently of the tissue or organ irradiated.

**RBE (relative biological effectiveness):** Measure of the effectiveness of a specific type of radiation for producing a specific biological outcome, relative to a reference radiation (generally, 250 kVp x-rays). For a defined endpoint,  $RBE = D_{ref}/D_{new}$ . For HZE particles, RBE generally is greater than 1, meaning that a lower dose of more effective HZE particles will have the same effect as a given dose of the reference radiation.

**RCT:** Radiation Coordination Team.

**RDD:** radiological dispersal device.

**RDWG:** Radiation Discipline Working Group.

**regolith:** A layer of loose, heterogeneous material covering solid rock on the surface of a moon or planet (including Earth).

**REIC:** risk of exposure-induced cancer incidence.

**REID (risk of exposure induced death):** Measure of risk used by NASA as a standard for radiation protection; reflects a calculation of the probability of death due to exposure to radiation in space.

**relative biological effectiveness (cf. RBE)**

**relative risk (cf. excess relative risk)**

**REM:** rapid eye movement.

**RF:** radiofrequency.

**RFI:** request for information.

**RHIC:** Relativistic Heavy Ion Collider (at BNL).

**RHO:** Radiation Health Officer.

**rigidity:** The momentum of a charged particle per unit charge. Determines the curvature of the particle's trajectory in a magnetic field. Two particles with different charge but the same rigidity will travel along a path having the same curvature in a given magnetic field.

**risk:** The probability of a specified effect or response occurring.

**risk coefficient:** The increase in the annual incidence or mortality rate per unit dose: (1) absolute risk coefficient is the observed minus the expected number of cases per person year at risk for a unit dose; (2) the relative risk coefficient is the fractional increase in the baseline incidence or mortality rate for a unit dose.

**risk cross section:** The probability of a particular excess cancer mortality per particle fluence (excluding delta rays).

**risk estimate:** The number of cases (or deaths) that are projected to occur in a specified exposed population per unit dose for a defined exposure regime and expression period; number of cases per person-gray or, for radon, the number of cases per person cumulative working level month.

**roentgen:** A unit of radiation exposure. Exposure in SI units is expressed in C kg<sup>-1</sup> of air.

**ROS:** reactive oxygen species.

**RRS:** radiation Research Society.

**RSNA:** Radiological Society of North America.

**R&T:** Research and Technology.

**RTG:** radioisotope thermoelectric generator.

## **-S-**

**SAA:** South Atlantic Anomaly.

**SACR:** Science Advisory Committee on Radiobiology.

**SAMPEX:** Solar Anomalous and Magnetospheric Particle Explorer.

**SAR:** specific absorption rate.

**SBIR:** Small Business Innovation Research.

**SCAR:** Smoke/Sulfate Clouds and Radiation Experiment.

**SCC:** squamous cell carcinoma/ small cell cancer.

**SCE:** sister chromatid exchange.

**SCLS:** small cell lung carcinoma.

**SD:** single dose.

**SD:** standard deviation.

**SDO:** Solar Dynamic Observatory.

**SEC:** Space Environment Center. (NOAA).

**secondary radiation:** radiation that has been generated by the interaction of radiation with the atoms or nuclei of a traversed material.

**SEE (single-event effect):** a class of effects in which damage results from a single ionizing particle traversing a microelectronic device, rather than the accumulated impact of a large number of particles.

**SEE:** single event effect/ Space Environment and Effects Program.

**SEER:** surveillance, epidemiology, and end results.

**SET:** Space Environment Testbeds.

**SEU (single event upset):** a change of state caused by ions or electro-magnetic radiation striking a sensitive node in a micro-electronic device.

**SGZ:** subgranular zone.

**SI:** International System of Units.

**sievert (Sv):** The special name for the SI unit of effective dose ( $E$ ), equivalent dose ( $H_T$ ), dose equivalent ( $H$ ), and organ dose equivalent ( $D_T$ ),  $1 \text{ Sv} = 1 \text{ J /kg}$ .

**SLSD:** Space Life Sciences Directorate (NASA).

**S&MA:** Safety and Mission Assurance (NASA).

**SMD:** Science Mission Directorate (NASA).

**SMO:** Science Management Office (NASA).

**SOHO:** Solar and Heliospheric Observatory.

**Solar cycle:** The periodic variation in the intensity of solar activity, as measured, for example, by the numbers of sunspots, flares, CMEs, and SPEs. The average length of solar cycles since 1900 is 11.4 y.

**solar flare:** The name given to the sudden release of energy (often  $>10^{32}$  ergs) in a relatively small volume of the solar atmosphere. Historically, an optical brightening in the chromosphere, now expanded to cover almost all impulsive radiation from the sun.

**solar-particle event (SPE):** An eruption at the sun that releases a large number of energetic particles (primarily protons) over the course of hours or days. Signatures of solar

energetic-particle events may include significant increases in types of electromagnetic radiation such as radio waves, x-rays, and gamma rays.

**solar wind:** The plasma flowing into space from the solar corona. The ionized gas carrying magnetic fields can alter the intensity of the interplanetary radiation.

**SOMD:** Space Operations Mission Directorate (NASA).

**spallation:** A high-energy nuclear reaction in which a high-atomic-number target nucleus is struck by a high-energy, light particle (typically a proton); this causes the target nucleus to break up into many components, releasing many neutrons, protons, and higher Z particles.

**SPE (cf. solar particle event).**

**Space Radiation Analysis Group (SRAG):** the radiation protection group at NASA's Johnson Space Center, responsible for radiation monitoring, projecting exposures, and ensuring adherence to principles of ALARA for crews on spaceflight missions.

**SPENVIS (SPace ENVironment Information System) :** a series of computer programs developed by the European Space Agency for the simulation of radiation effects in flight (<http://www.spennis.oma.be/>).

**SRA:** Society for Risk Analysis.

**sRBC:** Serum deprivation response factor-related gene product that binds to C-kinase.

**SRPE:** Space Radiation Program Element (NASA).

**SSA:** Social Security Administration.

**STEREO:** Solar-Terrestrial Relations Observatory (NASA mission).

**stochastic effects:** radiation effects attributed to the consequences of changes caused by radiation in one or a few cells; so called because the statistical fluctuations in the number of initial cells are large compared to the number of cells observed when radiation effects, such as cancer, become manifest (ICRP 1991). The probability of occurrence, rather than the severity, is a function of radiation dose.

**stochastic process:** process whereby the likelihood of the occurrence of a given event can be described by a probability distribution.

**stopping power (lineal stopping power):** The quotient of the energy lost (dE) by a charged particle in traversing a distance (dx) in a material. Can also be expressed as mass stopping power by dividing the lineal stopping power by the density ( $\rho$ ) of the material.

**STS:** Space Transportation System.

**STTR:** Small Business Technical Transfer Research.

## **-T-**

**TEDE:** total effective dose equivalent.

**TEPC:** tissue equivalent proportional counter.

**TGF:** transforming growth factor.

**TIGER:** Grid Generation Code.

**tissue weighting factor ( $w_T$ ):** A factor representing the ratio of risk of stochastic effects attributable to irradiation of a given organ or tissue to the total risk when the whole body is irradiated uniformly. The factor is independent of the type of radiation or energy of the radiation.

**TLD:** thermoluminescent dosimeter.

**TMG:** thermal micrometeoroid garment.

**TMI:** Three Mile Island.

**TOGA/COARE:** Tropical Ocean Global Atmosphere/Coupled Ocean-Atmosphere Experiment.  
transport (of radiation): the sequence of interactions between radiation traversing one or more materials and their atoms and nuclei; calculations of the relevant characteristics; transport code: computer program to calculate radiation transport.

**trapped radiation:** Ionized particles held in place by Earth's magnetic fields. Also known as the Van Allen belt.

**TRL:** Technology Readiness Level.

**TRMM:** Tropical Rainfall Measuring Mission.

**TVD:** tenth-value distance.

**TVL:** tenth-value layer.

## **-U-**

**UNSCEAR:** United Nations Scientific Committee on the Effects Of Atomic Radiation.

**US:** United States.

**USAF:** United States Air Force.

**US NRC:** United States Nuclear Regulatory Commission.

**USRA:** Universities Space Research Association.

**UV:** ultraviolet.

**-V-**

**vitreous:** The semifluid, transparent substance which lies between the retina and the lens of the eye.

**VSE:** Vision for Space Exploration.

**-W-**

**WBS:** Work Breakdown Structure.

**WHO:** World Health Organization.

**Wind:** a NASA spacecraft that observes the Sun and solar wind.

**WL:** working level.

**WLM:** working level month (170 h).

**wR:** radiation weighting factor.

**wT:** tissue weighting factor.

**-Z-**

**Z:** atomic number, the number of protons in the nucleus of an atom.