Advisory Circular

Subject: In-flight Radiation Exposure **Date:** 7/6/06 **AC No:** 120-61A

Initiated by:
AFS-210/AAM-600

1. PURPOSE. This advisory circular (AC) provides:

a. Information intended to augment (not alter or amend) existing programs an air carrier may be using to inform crewmembers about radiation exposure; and

b. Links to sources of information regarding in-flight radiation exposure.

2. CANCELLATION. This AC cancels:

a. AC 120-52, Radiation Exposure of Air Carrier Crewmembers, dated March 5, 1990.

b. AC 120-61, Crewmember Training on In-flight Radiation Exposure, dated May 19, 1994.

3. DEFINITIONS.

a. Conceptus. Any stage of prenatal development from fertilized egg to birth.

b. Galactic Cosmic Radiation. The ionizing radiation that originates outside the solar system, a main source of which is thought to be exploding stars (supernovae).

c. Ionizing Radiation. Refers to subatomic particles of matter (e.g., neutrons, protons, and electrons) and massless particles of energy (X-rays and gamma rays), with each particle having sufficient energy so that, on interacting with a material, it can cause an atom to lose an orbital electron. Low levels of ionizing radiation are a normal part of our environment. Substances that emit ionizing radiation are present in every cell in the body.

d. Solar Particle Event. An increase in ionizing radiation from the sun. Particles of ionizing radiation from the sun that reach the earth's atmosphere come from all directions because of the spreading effect caused by the interplanetary and earth's magnetic fields.

e. Solar Radiation. A severe disturbance in the sun that leads to a large flux of fast-moving, subatomic, ionizing-radiation particles (often called solar cosmic radiation) that penetrate the earth's magnetic field and enter the atmosphere. The particles interact with air

atoms in the same way as galactic cosmic radiation. A consequence is that, for varying lengths of time, ranging from a few minutes to more than a day, air travelers may be exposed to ionizing radiation from the sun as well as galactic cosmic radiation.

4. RELATED READING MATERIALS. The following reading materials are useful as further guidance and in developing training program subject material. For information on how to obtain these materials, see paragraph 11a.

a. "Radiation Protection Guidance to Federal Agencies for Occupational Exposure," Federal Register 52 (17): pp. 2,822-2,834 (January 1987).

- Unlawful employment practice for an employer, footnote to p. 2,829
- Recommendations regarding occupational exposure to radiation, section 7 on p. 2,832

b. National Council on Radiation Protection and Measurements, "Exposure of the Population in the United States and Canada from Natural Background Radiation." NCRP Report No. 94. Bethesda, MD, 1987.

c. Friedberg W, Copeland K, Duke FE, Nicholas JS, Darden Jr. EB, O'Brien III K, "Radiation Exposure of Aircrews," Occupational Medicine: State of the Art Reviews 17(2): 293-309, 2002.

- Galactic cosmic radiation in the atmosphere as related to altitude and latitude, pp. 294-298
- Effective dose of galactic cosmic radiation to the mother is a reliable estimate of the equivalent dose to the conceptus, p. 299
- Ionizing radiation from the sun, p. 299
- Recommended radiation exposure limits, p. 300
- Health concerns regarding radiation exposure, p. 300
- Risk of fatal cancer for a working-age population, p. 301
- Deaths in the general population from cancer: adults; p. 301; all ages, p. 303
- Risks from irradiation in utero, p. 302
- Inherited genetic defects from parental irradiation, p. 307
- Abnormalities at birth in the general population, p. 307

d. Hall, EJ, "Radiobiology for the Radiologist." Fifth Edition 2000, Lippincott Williams & Wilkins, Philadelphia, PA.

- Equivalent dose and effective dose defined, pp. 236-237

e. Bagshaw, Michael, "Cosmic Radiation in Commercial Aviation," International Academy of Aviation and Space Medicine, June 2004.

5. SOURCES OF EXPOSURE. The average annual doses of ionizing radiation a person in the United States typically receives from natural sources are set forth below:

Source	Effective dose, millisieverts (% of total)
Galactic Cosmic Radiation * (Uniform whole-body exposure)	0.27 (9%)
Inhaled Radon (Primarily to bronchial epithelium)	2.0 (68%)
Radioactive Material in the Ground (Uniform whole-body exposure)	0.28 (9%)
Radioactive Material in Body Tissues (Tissue doses vary)	0.40 (14%)
Total from natural sources = 2.95 (100%)	
* Includes 0.01 millisievert from air travel.	

6. EXPOSURE VARIABLES. Radiation received on a lower-latitude flight will be lower because of the greater amount of radiation shielding provided by the earth's magnetic field. This shielding is maximum near the equator and gradually decreases to zero as one goes north or south. Radiation levels over the polar regions are about twice those over the equator at the same altitudes. A map of high-latitude areas of concern is available on the following FAA Web site:

http://www.faa.gov/education_research/research/med_humanfacs/aeromedical/radiobiology/solarradiation/index.cfm.

a. A solar radiation alert system developed by the FAA's Civil Aerospace Medical Institute, with data provided by the Space Environment Services Center of the National Oceanic and Atmospheric Administration (NOAA), alerts users of the beginning of a disturbance on the sun that can lead to high-dose rates of ionizing radiation in the earth's atmosphere. Solar radiation alerts are transmitted worldwide to subscribers of NOAA's Weather Wire Service. A message is transmitted at the beginning and end of an alert. A test message is transmitted daily. Responding to an alert by flying at a lower altitude can significantly reduce radiation exposure in high-latitude areas of concern.

b. A description of the methodology associated with the solar radiation alert system can be found by linking to the technical report entitled "Solar Radiation Alert System" (DOT/FAA/AM-05/14), available on the following FAA Web site at: http://www.faa.gov/library/reports/medical/oamtechreports/2000s/media/0514.pdf.

7. RECOMMENDED LIMITS.

a. When considering the harmful health effects of postnatal (child or adult) exposure to ionizing radiation, the current practice is to express the amount of radiation received in terms of effective dose. If the radiation exposure is to a conceptus (any stage of prenatal development from fertilized egg to birth), dose is expressed in terms of equivalent dose. The unit of both effective dose and equivalent dose is the sievert, which is a measure of the biological harm that ionizing radiation may cause: 1 sievert = 1000 millisieverts.

b. The recommended occupational exposure limit for ionizing radiation is a 5-year average effective dose of 20 millisieverts per year, with no more than 50 millisieverts in a single year. For a pregnant crewmember, the recommended limit for the conceptus is an equivalent dose of 1 millisievert, with no more than 0.5 millisievert in any month.

c. The FAA has linked to its Web site the following two technical reports regarding radiation exposure during pregnancy:

(1) "In-flight Radiation Exposure During Pregnancy" (published by the American College of Obstetricians and Gynecologists), at: (http://www.acog.org/from_home/publications/green_journal/2004/v103n6p1326.pdf).

(2) "Galactic Cosmic Radiation Exposure of Pregnant Aircrew Members II" (FAA technical report DOT/FAA/AM-00/33), at: (http://www.faa.gov/library/reports/medical/oamtechreports/2000s/media/00_33.pdf).

8. RISK ASSOCIATED WITH EXPOSURE. The probability of a radiation-caused cancer or genetic defect is related to the total amount of radiation accumulated by an individual. Based on current scientific thinking, any exposure to radiation can be harmful and increase the risk of cancer. At very low exposures, however, the estimated increases in risk are very small.

a. Individuals exposed to excessive levels of ionizing radiation are at increased risk for cancers and are at risk of passing on genetic defects to future generations. Ionizing radiation can cause changes in the chemical balance of cells, which can cause cell damage or cell death. In some cases, there may be no effect. In other cases, the cell may survive but become abnormal, either temporarily or permanently. An abnormal cell may become malignant.

b. The likelihood of developing cancer because of occupational exposure to galactic cosmic radiation is a small addition to health risks experienced by the general population. Currently, it is not possible to establish that an abnormality or disease in a particular individual resulted from exposure to galactic cosmic radiation at the doses likely to be received while flying.

9. MANAGING EXPOSURE.

a. How to Calculate Exposure. The FAA has computer programs available on its Web site, called CARI-6 and CARI-6M. These programs can be used to estimate the effective dose of galactic cosmic radiation. No programs are currently available for use in estimating the effective dose received from a solar particle event. The dose of ionizing radiation that an individual might receive during a solar particle event cannot be estimated in advance. Research is currently being conducted on how best to estimate flight doses on the basis of satellite and ground-level measurements made during an event.

(1) CARI-6. This program calculates the effective dose of galactic cosmic radiation received by an individual (adult) on an aircraft flying a great-circle route between any two airports in the world. The program takes into account changes in altitude and geographic

location during the course of a flight, as derived from the flight profile entered by the user. Based on the date of the flight, appropriate databases are used to account for effects of changes in the earth's magnetic field and solar activity on galactic radiation levels. The program also calculates the effective dose rate from galactic cosmic radiation at any location in the atmosphere at altitudes up to 60,000 feet. The Web sites for CARI-6 are:

http://jag.cami.jccbi.gov./cariprofile.asp; and

http://www.faa.gov/education_research/research/med_humanfacs/aeromedical/radiobiology/cari6/index.cfm.

(2) CARI-6M. This program does not require a great-circle route between origin and destination airports; it allows the user to specify the flight path by entering the altitude and geographic coordinates of waypoints. The Web site for CARI-6M is:

http://www.faa.gov/education_research/research/med_humanfacs/aeromedical/radiobiology/cari6m/index.cfm.

b. How to Reduce Exposure. The amount of radiation exposure received while flying depends on the amount of time in the air, altitude, latitude, and solar activity. (Provided air carriers respond to solar radiation alerts, ionizing radiation from the sun should not contribute enough additional radiation to exceed recommended exposure limits.)

10. RADIOACTIVE MATERIAL SHIPMENTS. In calculating total exposure to ionizing radiation, consider exposure to radioactive cargo in addition to exposure to galactic cosmic and solar radiation. The carriage of such cargo is limited and controlled by the following regulations:

a. Radiation Level Limitations. Title 49 of the Code of Federal Regulations (49 CFR) part 175, section 173.441.

b. Notification of Pilot in Command. Title 49 CFR, part 175, section 175.33.

c. Special Limitations and Requirements for Class 7 (Radioactive) Materials. Title 49 CFR part 175, section 175.700.

11. FURTHER INFORMATION.

a. For questions regarding in-flight radiation exposure, contact:

U.S. Department of Transportation
Federal Aviation Administration
Office of Aerospace Medicine
Radiobiology Research Team, AAM-610
Civil Aerospace Medical Institute
Oklahoma City, OK 73125
9-amc-aam610-radiation@faa.gov.

http://www.faa.gov/education_research/research/med_humanfacs/aeromedical/radiobiology/index.cfm.

b. For questions regarding radioactive cargo contact:

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Office of Hazardous Materials Technology
Radioactive Materials Branch, PHH-23
400 Seventh Street SW
Washington, DC 20590
http://hazmat.dot.gov

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