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Flight Crews and Cabin Crews Encouraged to Increase Awareness of In-flight Ionizing Radiation

Crew members who regularly fly at high cruise altitudes receive higher levels of ionizing radiation than the general population. The increased risk appears to be slight, but greater attention is being focused on monitoring of, and education about, ionizing radiation.

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All life is continually exposed to ionizing radiation. Ionizing radiation comes from several sources — from the earth (*terrestrial* radiation), from space (*cosmic* radiation, which produces *ionizing* radiation after colliding with nitrogen, oxygen and other atoms in the atmosphere), from a combination of cosmic radiation and secondary radiation (*galactic* radiation) and even from radioactive atoms in the human body.

Air carrier crew members are exposed to more cosmic radiation — high-energy subatomic particles and photons (energy) that originate primarily outside the solar system — than most of the general population. The less-dense, high-altitude atmosphere offers less protection against ionizing radiation, which produces electrically charged atoms known as ions. An ion can react with surrounding matter, including body tissues, and lead to unwanted biological effects, such as cancer, genetic defects and fetal damage; some of ionizing radiation's effects on tissues are cumulative.

Ionizing radiation is also produced — but carefully controlled for useful benefits — by medical X-ray examinations, industrial products and pharmaceuticals for medical treatments and diagnostics.

Natural and manmade barriers provide considerable protection against some forms of ionizing radiation. Alpha particles have little penetrating power beyond the first layer of skin, and even a sheet of paper will obstruct them. X-rays and gamma rays pass through the body, but can be stopped by a thick shielding of lead, concrete or water. Neutrons (which are byproducts of nuclear power plants) also require barriers of water or concrete.[1]

For most people on the earth's surface, the atmosphere offers considerable insulation against cosmic rays. For example, at Oklahoma City, Oklahoma, U.S. (about 1,200 feet [360 meters] above sea level), galactic radiation is approximately 0.5 percent of the galactic radiation at 39,000 feet (11,895 meters).[2]

The U.S. Federal Aviation Administration (FAA) in 1994 issued an advisory circular[3] that recommends subjects that air carriers should cover in programs to inform crew members about the known health risks of exposure to ionizing radiation, so that they can make informed decisions about their work in commercial aviation. The recommended subjects include information about:

- Types and amounts of radiation received during air travel, compared with other sources of exposure such as radon in the home and medical X-rays;

- Variables that affect the amount of radiation exposure in flight;

- Guidelines for exposure to ionizing radiation, including recommended limits for workers and the general public;
- The risks — including cancer and genetic defects — to crew members and fetuses associated with exposure to cosmic radiation;
- Special considerations relating to pregnancy;
- Management of exposure to radiation risks, including frequency of flights or types of flight assignments, and the use of monitoring devices or a computer program;
- Radioactive material shipments as a source of radiation exposure; and,
- Any other subjects that the air carrier believes would be useful in connection with the subject.

In-flight ionizing radiation exposure of flight crew and cabin crew for flights at specific altitudes and routes at specified dates has been studied and measured. Most exposure to ionizing radiation by crew members occurs during flight at the higher altitudes and higher latitudes (away from the equator and toward the polar regions). The intensity of the ionizing radiation also increases during periods of increased solar activity that occur approximately every 11 years.[2] (The most recent solar maximum occurred in 1989.)

In addition to the 11-year solar cycle, solar flares — powerful magnetic disturbances on the sun — emit various kinds of ionizing radiation. There is a small risk that crews could be exposed to even greater levels of ionizing radiation during intense solar flares, such as those that occurred on Feb. 23, 1957, and on Sept. 29, 1989.

The human body can tolerate some low-level ionizing radiation effects, but further exposure increases health risks including the risk of developing cancer; the risk of genetic mutations in egg cells and sperm cells; and the risk of damage to a developing embryo or fetus.

Groups of experts have established safe exposure levels for specific periods of time (e.g., one year) and also for a lifetime cumulative dose. Ionizing radiation limits are recommended by the International Commission on Radiological Protection, the U.S. National Council on Radiation Protection and Measurements, the U.S. Environmental Protection Agency (EPA), the FAA and other organizations.

One international unit of measure for ionizing radiation is the sievert (Sv). Smaller quantities are measured in millisieverts (mSv — one-thousandth of a sievert) and microsieverts (µSv — one-thousandth of a millisievert). An Sv is not an absolute amount of radiation, but rather a measure of the biological effect of the ionizing radiation. This allows comparison of different radiation types that produce different effects for the same exposure time.[1] [The sievert has replaced the rem as the international unit of measurement; one sievert is equal to 100 rem.]

The basic EPA ionizing radiation guideline is a maximum of five mSv (500 millirem) per year. For adult male and nonpregnant female flight crew and cabin crew, the FAA recommended maximum exposure is a maximum 20 mSv per year, averaged over five years. For pregnant females, recommended maximum exposure is a more conservative two mSv until the end of pregnancy, with a maximum exposure of 0.5 mSv per month.

A typical chest X-ray exposes the subject to 0.02–0.05 mSv. Ground-level ionizing radiation across the contiguous United States averages about 0.06 µSv per hour.[5] At 35,000 feet (10,675 meters), the dose-equivalent rate from cosmic radiation is about four µSv per hour. At 41,000 feet (12,505 meters) at polar latitudes, the dose-equivalent rate is about eight µSv per hour.[6]

The biological effects of low levels of radiation exposure are so small they are difficult to determine with certainty, particularly since some effects may not be apparent for many years. However, radiation protection standards assume that there is a direct relationship between dose (level of exposure) and effect, even at small doses, and that effects are cumulative.

Table 1 (page 3) shows estimates of the ionizing radiation doses received by aircraft occupants during flights within the United States and also during transoceanic flights.

The flight crews and cabin crews of flights that reach the higher altitudes and the higher latitudes receive the highest doses of ionizing radiation. The accumulated dose is proportionate to the total hours of exposure at these altitudes and latitudes, but it is also influenced by solar activity.[7]

The flights shown in Table 1 range from a potential exposure of 0.0001 mSv to 0.0644 mSv. At the exposure rate of 0.0644 mSv per flight, it would take approximately 78 flights to reach the EPA-recommended yearly maximum exposure level of five mSv — about 6.5 flights per month.

Studies have estimated that for the adult U.S. population, the risk of dying of cancer from all causes is approximately 220 in 1,000.[4,8] (For every 1,000 persons, 220 would be expected to die of cancer.) Radiation exposure caused by 20 years of high-altitude flight may increase this risk to as much as 225 cancer deaths in 1,000 people.[4]

These figures suggest that flight crew and cabin crew face a small increase in the likelihood of incurring a radiation-induced ailment under such circumstances. An assessment of in-flight ionizing radiation risks must also take into account the age and sex of the person exposed. If, for example, the risk of developing a certain type of leukemia occurs 25 years after exposure to specified levels of high-altitude ionizing radiation, the impact of the risk will be greater for younger

Table 1
Ionizing Radiation Exposures on Specific Aircraft Flights[a]

Nonstop One-way Flights

Origin and Destination	Block Hours[b]	Air Time Hours	Altitude[c] Highest Altitude (feet in thousands)	Altitude[c] Mean Altitude (feet in thousands)	Calculated Dose µSv	Calculated Dose mSv	Calculated Dose Millirem
Minneapolis MN – New York NY	2.1	1.8	37	31	7.7	0.0077	0.77
London, England – Dallas/Fort Worth TX	10.1	9.7	39	32	36.1	0.0361	3.61
Los Angeles CA – London, England	10.2	9.7	37	34	44.3	0.0443	4.43
London, England – New York NY	7.3	6.8	37	34	32.5	0.0325	3.25
Seattle WA – Washington DC	4.4	4.1	37	34	19.7	0.0197	1.97
San Francisco CA – Chicago IL	4.1	3.8	41	35	19.0	0.019	1.90
New York NY – Seattle WA	5.3	4.9	39	34	24.5	0.0245	2.45
Tokyo, Japan – New York NY	12.6	12.6	41	35	59.7	0.0597	5.97
Chicago IL – London, England	7.7	7.3	37	35	36.9	0.0369	3.69
New York NY – Tokyo, Japan	13.4	13.0	43	36	64.4	0.0644	6.44
London, England – Chicago IL	8.3	7.8	39	35	41.5	0.0415	4.15
Athens, Greece – New York NY	9.7	9.4	41	39	56.1	0.0561	5.61
Seattle WA – Portland OR	0.6	0.4	21	12	0.1	0.0001	0.01
Houston TX – Austin TX	0.6	0.5	20	12	0.1	0.0001	0.01
Tampa FL – St. Louis MO	2.2	2.0	31	25	4.0	0.004	0.4
Denver CO – Minneapolis MN	1.5	1.2	33	27	3.3	0.0033	0.33
Los Angeles CA – Honolulu HI	5.6	5.2	35	33	12.0	0.012	1.20
Honolulu HI – Los Angeles CA	5.6	5.1	40	34	13.9	0.0139	1.39
Chicago IL – New York NY	2.0	1.6	37	29	5.9	0.0059	0.59
Los Angeles CA – Tokyo, Japan	12.0	11.7	40	34	35.2	0.0352	3.52
Tokyo, Japan – Los Angeles CA	9.2	8.8	37	34	27.7	0.0277	2.77
Washington DC – Los Angeles CA	5.0	4.7	35	32	16.5	0.0165	1.65
New York NY – Chicago IL	2.3	1.6	39	31	8.3	0.0083	0.83

[a] Based on a heliocentric potential of 457 millivolts (mV) — the extrapolated 1,000-year average.
[b] The block hours of a flight begin when the aircraft leaves the gate (blocks) before takeoff and end when it reaches the gate after landing.
[c] Including initial climb and final descent.

1 sievert (Sv) = 100 rem 1 millisievert (mSv) = 100 millirem (mrem) 1 microsievert (µSv) = 0.1 millirem (mrem)

Source: Dr. Wallace Friedberg, U.S. Federal Aviation Administration (FAA), Civil Aeromedical Institute

exposed crew members than older ones, because the forecast onset of the leukemia would more closely coincide with the forecast life expectancy for the older person.[9] Likewise, a postmenopausal female crew member would not face the risk of transmitting possible unwanted genetic changes to future generations, as would males and premenopausal females.

An FAA report notes: "The likelihood of developing fatal cancer because of occupational exposure to galactic radiation is a small addition to the general population risk. ... Any risk to a child of a serious handicap of genetic origin because of a parent's occupational exposure to galactic radiation would be a very small addition to health risks experienced by all children."[2]

Real-time monitoring of exposure to ionizing radiation by flight crews and cabin crews is made possible by a complex dosimeter, which is standard equipment on high-altitude supersonic transport flights. The instrument also calculates the total dose of ionizing radiation accumulated during the flight.

The dosimeter display has color-coded sectors — green for "safe" ionizing radiation levels, yellow for "building" ionizing radiation levels and red for "unsafe" ionizing radiation levels. Thus, a pilot who knows that unsafe radiation levels have been reached during flight can descend to a lower altitude, where the ionizing radiation level is diminished by the shielding effects of the denser air.

A computer software program, CARI-3, which calculates the ionizing radiation dose that can be expected for a specific flight, was developed by Dr. Wallace Friedberg and other scientists at the FAA Civil Aeromedical Institute (CAMI). The computer program calculates the dose based on flight date, flight distance, estimated times at en route altitudes, and heliocentric potential, which is the degree of solar activity. Data regarding heliocentric potential are available via modem from CAMI. The DOS (disk operating system)-based program is reported to be user-friendly.[10]

Although it makes sense for flight crews to minimize to the extent practical the risks associated with ionizing cosmic radiation, those risks must be kept in perspective. The FAA reports that “radiation is not likely to be a factor that [should] limit flying for a nonpregnant crew member.” But it also notes that “on some flights the galactic radiation received by an unborn child may exceed the recommended limits, depending on the [crew member] woman’s work schedule.”[2] Pregnant crew members should pay particular attention to monitoring or calculating their exposure.♦

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