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JAA Adopts Requirements for Assessing Aircrew Exposure to Cosmic Radiation

The European Joint Aviation Authorities in 2001 established requirements for operators to educate crewmembers of health risks, to adjust work schedules of those exposed to high levels of radiation and to measure or to sample radiation during flights above 49,000 feet. The exposure limit recommended by JAA is about eight times lower than that recommended in the United States.

Robert W. Moorman

Regulations issued in 2001 by the European Joint Aviation Authorities (JAA) provide standards by which aircraft operators can estimate the exposure of flight crewmembers and cabin crewmembers to cosmic radiation and ensure that recommended limits are not exceeded.

Cosmic radiation is the collective term for the radiation of high-energy subatomic particles from space (e.g., from exploding stars) and, to a lesser extent, from the sun, and the secondary (ionizing) radiation produced when the high-energy subatomic particles interact with nitrogen, oxygen and other elements of Earth's atmosphere. Ionization involves the displacement of electrically charged particles (electrons) from atoms and the breakup of the nuclei of atoms, and the resultant production of ions. Ionization that occurs in body tissues or body organs can lead to cancer and to genetic defects that can be passed from parents to offspring.[1, 2, 3, 4]

The international unit of measurement of the biological harm that might be caused by ionizing radiation is the sievert.[5] One sievert equals 1,000 millisieverts (mSv).

JAA in January 2001 amended Joint Aviation Requirements — Operations (JAR-OPS 1), the regulations governing the operation of commercial air transport airplanes, to require operators to "take account of the in-flight exposure to cosmic radiation of all crewmembers while on duty [and to] take the following measures for those crew liable to be subject to exposure of more than 1 mSv per year:

- "Assess their exposure;
- "Take into account the assessed exposure when organizing working schedules with a view to reduce the doses of highly exposed crewmembers;
- "Inform the crewmembers concerned of the health risks their work involves;
- "Ensure that the working schedules for female crewmembers, once they have notified the operator that they are pregnant, keep the equivalent dose to the fetus as low as can reasonably be achieved and in any case ensure that the dose does not exceed 1 mSv for the remainder of the pregnancy; [and,]
- "Ensure that individual records are kept for those crewmembers who are liable to [be subject to] high exposure. These exposures are to be notified to the individual on an annual basis and also upon leaving the operator."[6]

The regulations prohibit operation of an airplane above 49,000 feet unless the airplane is equipped with an instrument that

measures and continually indicates the dosage of cosmic radiation being received by crewmembers, and that provides the cumulative dosage for each flight; or unless the operator uses an approved system for quarterly radiation sampling.[7]

The regulations also require the pilot-in-command to begin a descent as soon as practicable when the cosmic-radiation-dose rate exceeds the limits specified in the company operations manual.

Advisory material issued by JAA cites one acceptable method for determining whether crewmembers will be exposed to more than 1 mSv of cosmic radiation per year.[8] The determination is conducted with reference to data (Table 1) produced by a computer program. The program, called CARI-3, was developed by the U.S. Federal Aviation Administration (FAA) Civil Aeromedical Research Institute (CARI, now the Civil Aerospace Medical Institute [CAMI]).[9]

Table 1
Estimated Annual Flight Hours to Receive Effective Dose of 1 Millisievert of Cosmic Radiation

Altitude (feet)	Kilometers	Hours at Latitude 60° N	Hours at Equator
27,000	8.23	630	1,330
30,000	9.14	440	980
33,000	10.06	320	750
36,000	10.97	250	600
39,000	11.89	200	490
42,000	12.80	160	420
45,000	13.72	140	380
48,000	14.63	120	350

Source: Joint Aviation Authorities

The data provide estimates of the number of flight hours — accumulated in one year at various altitudes at 60 degrees north latitude and at the equator — that would result in exposure to a cosmic-radiation dose of 1 mSv.

The advisory material said, "Doses from cosmic radiation vary greatly with altitude and also with latitude and with the phase of the solar cycle."

The atmosphere and the earth's magnetic field provide some shielding against incoming cosmic radiation.[10] Deflection of high-energy particles by the magnetic field is greatest at the equator and decreases to zero at the poles. Shielding by the atmosphere decreases as altitude increases (i.e., as atmospheric density decreases).

"If flights are limited to heights of less than eight kilometers (27,000 feet), it is unlikely that annual doses will exceed 1 mSv," the advisory material said. "No further controls are necessary for crewmembers whose annual dose can be shown to be less than 1 mSv."

The advisory material recommends that, for crewmembers whose exposure to cosmic radiation is likely to exceed 1 mSv per year, the operator "should arrange, where practicable, to keep [their] exposure below 6 mSv per year."

"For the purpose of this regulation, crewmembers who are likely to be exposed to more than 6 mSv per year are considered highly exposed, and individual records of exposure to cosmic radiation should be kept for each crewmember concerned," the advisory material said.[11]

Included in the information that operators are required to provide their crewmembers is specific information on the risks of cosmic radiation to female crewmembers. The major risks to an unborn child from exposure to cosmic radiation are structural abnormalities, mental retardation and an increased lifetime risk of fatal cancer.[12]

"Female crewmembers should know of the need to control doses during pregnancy, and [that] the operator [should be] notified so that the necessary dose-control measures can be introduced," the advisory material said.[13]

Equipment capable of measuring cosmic radiation is installed in all Concorde supersonic transports, which entered commercial service in 1976. The monitoring equipment includes a rate meter that provides an instantaneous reading of total radiation dose equivalent. The readings are recorded at the beginning and end of each flight. The equipment also includes an alarm that activates if the dose equivalent reaches 0.1 mSv per hour, which could occur from a solar flare.

"It is reassuring that in the 100,000 or so sectors flown by the combined British Airways and Air France Concorde fleets to date, no Concorde has had to activate an emergency descent because of high radiation from a solar flare," said Michael Bagshaw, M.D., head of occupational and aviation medicine for British Airways.[14] He said that Concorde crews have an annual exposure of approximately 4 mSv per year.

Cosmic-radiation-measurement equipment currently is not manufactured and, thus, is not available for installation in aircraft. Therefore, the new JAA regulations include a provision for an operator to use an alternate procedure for monitoring exposure rates.

The alternate procedure involves sampling cosmic-radiation exposure every three months on 16 route sectors that include flights above 49,000 feet. An operator that conducts fewer than 16 flights above 49,000 feet during the period must sample cosmic-radiation exposure on each flight.

Guidance material said that the sampling should be conducted in conjunction with a radiological agency or "similar

organization acceptable to [JAA]" and that the results of the sampling should be provided to JAA.[15]

In the United States, FAA has no plans to adopt regulations on cosmic-radiation exposure.

"We are not planning to put out a rule because we don't see this as an immediate risk," said Fred Tilton, M.D., deputy air surgeon for FAA. "We're dealing with this issue [of exposure to cosmic radiation] from an educational perspective. We want to ensure that passengers and crewmembers alike are given all the necessary information on cosmic radiation and what the consequences might be."[16]

Tilton said that the risks to flight crews and passengers of overexposure to cosmic radiation are small.

"Airlines have flown polar routes since the 1950s, and we've not seen the dosage come close to the maximum allowable risk considered safe," he said. "We have not been able to determine that cosmic-radiation exposure has directly caused cancer in anyone. This is why we are looking more at education than regulation."

FAA recommends that crewmembers and passengers be exposed to no more than 20 mSv per year over a five-year period, with a maximum of 50 mSv in one given year. The FAA recommendations are based on guidelines established by the International Commission on Radiological Protection (ICRP).[17]

FAA's recommended limit for a pregnant crewmember is 1 mSv. After that level has been reached, FAA recommends that the crewmember not fly until after the child is born. ICRP recommends that pregnant crewmembers be reassigned to flights that are relatively short in duration and are conducted at relatively low altitudes, or be reassigned to ground duties for the remainder of the pregnancy.

The Air Line Pilots Association, International (ALPA), CAMI and the Medical University of South Carolina's Department of Biometry and Epidemiology are conducting a two-phase study of possible harmful effects of cosmic radiation. The first phase of the study involves assessment of the incidence of cancer among pilots through a survey of more than 11,500 active and retired airline pilots.

As part of this project, an extensive database on exposure rates using a flight-history survey will be constructed. Phase 2 of the study will involve determination of whether chronic low-dosage radiation exposure can be detected from biological markers.

Capt. Gary Butler, Ph.D., director of aeromedical research for ALPA's Human Performance Committee said that the ongoing study already has produced a significant finding.

"What we have found is a fourfold increase of melanoma [skin cancer] among pilots, compared to a standardized population," he said. "The question to ask is why are we seeing this? There are a number of reasons, one of which is cosmic radiation. But there is no evidence to suggest that cosmic radiation is a sole cause of cancer."[18]

Butler said that among the pilots with a higher incidence of melanoma were those who fly at lower altitudes and at latitudes where cosmic radiation is not a factor.

Wallace Friedberg, Ph.D., team leader of the CAMI Radiobiology Research Team, said, "We know that there is a potential for harm from cosmic radiation, but quantifying the problem becomes difficult."[19]

Friedberg said that in recent years, there have been several studies that have found increased incidences of cancer among flight crewmembers. "[Nevertheless,] it is not clear whether radiation is the problem," he said. "Some uncertainties remain."

The JAA regulations on cosmic radiation are likely to generate more studies, more meetings and more interest among scientists, operators and regulators. Interest in the possible adverse effects of cosmic radiation has grown beyond intercontinental air travel. Friedberg was invited to speak at an environment-related conference late last year. His topic: possible health effects from cosmic radiation exposure on a trip to Mars.♦

Notes

1. U.K. Department for Transport, Local Government and the Regions. *Protection of air crew from cosmic radiation: Guidance material*. <www.aviation.dtlr.gov.uk/cosmic/index.htm> Dec. 18, 2001.

2. Mohler, Stanley R. "Flight Crews and Cabin Crews Encouraged to Increase Awareness of In-flight Ionizing Radiation." *Human Factors & Aviation Medicine*. Volume 43 (March–April 1996): 1–4.

3. Friedberg, Wallace; Snyder, Lorrenza; Faulkner, Donald N.; Darden, Edgar B. Jr.; O'Brien, Keran. "Effects of Radiation Exposure on Air Carrier Crew Members Examined." *Cabin Crew Safety* Volume 26 (July–August 1993): 1–8.

4. U.S. Federal Aviation Administration (FAA). Advisory Circular (AC) 120-52. *Radiation Exposure of Air Carrier Crewmembers*. March 5, 1990.

5. FAA Office of Aviation Medicine. *Radiation Exposure of Air Carrier Crewmembers II*, Report No. DOT/FAA/AM-92/2. A special report prepared by the FAA Civil Aeromedical Institute. January 1992.

6. Joint Airworthiness Authorities (JAA). Joint Aviation Requirements — Operations (JAR-OPS) 1.390, *Cosmic Radiation*.

7. JAA. JAR-OPS 1.390 and JAR-OPS 1.680, *Cosmic Radiation Detection Equipment.*

8. JAA. Advisory Circular Joint — Operations (ACJ-OPS) 1.390(a)(1), *Explanatory Information.*

9. The CARI computer program provides estimates of cosmic radiation exposure for specific flights. Two current versions of the program — CARI-6 and CARI-6M — can be downloaded from the FAA Civil Aerospace Medical Institute (CAMI) Radiobiology Research Team's Internet site, <www.cami.jccbi.gov/aam-600/610/600radio.html>. The CARI-6 program provides exposure estimates based on a great-circle route between the departure point and destination, and cruise altitude, specified by the user. The CARI-6M program provides exposure estimates based on great-circle routes between various waypoints and cruise altitudes specified by the user.

10. Friedberg et al.

11. JAA. ACJ-OPS 1.390(a)(2), *Explanatory Information.*

12. FAA, CAMI, Radiobiology Research Team. *What Commercial Aircraft Crewmembers Should Know About Their Occupational Exposure to Ionizing Radiation*, <www.cami.jccbi.gov/research/610/600radio.html>, Sept. 13, 2001.

13. JAA. ACJ-OPS 1.390(a)(3), *Explanatory Information.*

14. Bagshaw, Michael. E-mail communication with Moorman, Robert. Alexandria, Virginia, U.S. Aug. 20, 2001. Flight Safety Foundation, Alexandria, Virginia, U.S.

15. JAA. ACJ-OPS 1.680(a)(2), *Quarterly Radiation Sampling.*

16. Tilton, Fred. Telephone interview by Moorman, Robert. Alexandria, Virginia, U.S. Aug. 1, 2001. Flight Safety Foundation, Alexandria, Virginia, U.S.

17. FAA Office of Aviation Medicine. *Radiation Exposure of Air Carrier Crewmembers II.*

18. Butler, Gary. Telephone interview by Moorman, Robert. Alexandria, Virginia, U.S. Aug. 6, 2001. Flight Safety Foundation, Alexandria, Virginia, U.S.

19. Friedberg, Wallace. Telephone interview by Moorman, Robert. Alexandria, Virginia, U.S. Aug. 3, 2001. Flight Safety Foundation, Alexandria, Virginia, U.S.

About the Author

Robert W. Moorman has reported on the aerospace industry for more than 17 years. He has been a staff editor of several publications, including Aviation Week & Space Technology, Air Transport World, Air Line Pilot *and* Professional Pilot. *He holds a bachelor of arts degree from the University of Northern Colorado and has taken graduate-level courses at the University of Minnesota.*

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