***PROGRESS ON THE HORIZON OF IN-FLIGHT RADIATION EXPOSURE***

*By Captain Joyce May, APA Aeromedical Committee Deputy Chairwoman*

In the later weeks of October 2003, a number of strong solar flares occurred which fueled many questions and concerns among our pilots. These questions concerned in-flight radiation exposure as a result of solar activity. The APA Aeromedical Committee has been actively working on the issue of solar activity and in-flight radiation exposure for the last several years. This is a review of in-flight radiation exposure and a report on the solar activity of October 2003. Additionally this will provide you with an update on what new information has emerged over the last several years on in-flight radiation exposure and the very positive report of progress that has been made in dealing with it at American.

***In-Flight Radiation Exposure***

A quick review of radiation will help clarify how in-flight exposure affects you. Please forgive some of the technical jargon but a certain amount of it is unavoidable with this topic! Ionizing radiation is radiation of sufficient energy to penetrate the surface of our bodies and cause cellular disruption. It is a naturally occurring part of our environment emanating from the soil and rocks--known as terrestrial radiation, and from space--known as cosmic radiation. Air crewmembers receive significantly higher exposure to ionizing radiation than our fellow ground-bound citizens by virtue of the amount of time we spend aloft. This in-flight ionizing radiation comes from deep space galactic radiation, and also from the sun known as solar radiation—collectively both are referred to as cosmic radiation.

The more ionizing radiation someone is exposed to, the greater damage it does to their body, particularly causing chromosomal (DNA) damage. These effects are cumulative over the course of lifetime exposure. Radiation exposure is measured in units called “sieverts”; in-flight radiation is usually discussed in doses of millisieverts (mSv), which is one thousandth (1/1000) of a sievert.

Ultraviolet (UV) radiation, which is the kind of radiation you wear sunscreen to protect your skin from, is non-ionizing radiation (it does not penetrate beyond the surface of the skin), nor is it an in-flight exposure issue since commercial jet aircraft windshields manufactured since the 1950’s screen out practically all UV rays. Although this was originally done to protect the aircraft instruments, it also means that you can skip the wearing of sunblock on the flight deck.

The Earth’s atmosphere shields our planets’ surface from most of the cosmic radiation that emanates our way. However, flying at jet cruising altitudes, where there is less atmospheric shielding above the aircraft, and where enough cosmic radiation gets inside of the aircraft to impact the aircraft’s occupants, results in greater exposure to those on board to cosmic radiation. Most jet air crewmembers receive about 2 to 4 mSv additional exposure to cosmic radiation per year than the general population. Crews with regular flights to Europe and Asia may receive more.

***Air Crewmembers As "Radiation Workers"***

In the U.S., the federal government regulates atomic plant workers, x-ray technicians, and others who are occupationally exposed to radiation. The government requires companies to formally notify workers that they are exposed to radiation and educate them about possible health effects arising from that exposure. Companies also regularly monitor and control levels of employee exposure. Employees receive health exams, and their health records are tracked to detect any negative health trends.

The FAA has acknowledged that jet aircrew are "occupationally exposed" to radiation. This means that in the course of performing their duties, aircrew typically are exposed to more than 1 mSv of radiation per year. 1 mSv/year is the recommended amount for a member of the general population. In 1994, the FAA issued an Advisory Circular recommending that aircrew receive training about their radiation exposure and the associated hazards, but airlines were not given any specific guidance at that time on how to carry out this recommendation.

Since aircrew fall under the jurisdiction of the FAA, it has been the FAA's responsibility to regulate us as the occupationally exposed radiation workers they admit we are, but for whatever reason they have not done so. They did establish the Civil Aeromedical Institute (CAMI) with the aim of providing guidance to airlines and aircrew on how to deal with this issue, but CAMI has no regulatory authority. The guidelines they issue are only recommendations—they are not legally mandated. Ironically, the average aircrew employee is more highly exposed to radiation than any other class of radiation worker in the U.S., yet are the only ones not regulated as such. In Europe, the picture is different. Since May 2000, European aircrew have been regulated as radiation workers, and they receive protections similar to other radiation-exposed workers in the U.S. For now, U.S. crewmembers can calculate their own in-flight exposure amounts at the CAMI website at http://www.cami.jccbi.gov/radiation.html. The accuracy of this computer-modeled program by CAMI has been verified as having a reasonable degree of accuracy by other independent measuring sources. Be aware that a special adjustment must be made to the dose calculation for increases caused by solar flare activity. The calculation adjustment is explained on the web site.

***Understanding The Variables Affecting In-Flight Exposure***

Cosmic radiation is scattered around to both the sunny and dark sides of the Earth, so day versus night flying does not appreciably change how much cosmic radiation you receive during flight. The amount of radiation that anyone—passenger or crew—traveling in an aircraft receives, is a factor of:

- Aircraft altitude: Radiation levels double with each approximate 6,500-foot climb. So doing some math calculations, the atmospheric cosmic radiation at FL390 is about 64 times greater than at sea level. At FL 330, the radiation level is significantly lower at about 35 times more than sea level amounts. Therefore, if climbing to the next flight level doesn't save you fuel, time, provide a much better ride, or some other important operational consideration, then think twice about it.
- Aircraft latitude: As an aircraft flies closer to the poles, occupants are exposed to greater amounts of radiation. At latitude 70º N, cosmic radiation levels can be as much as four times higher than at 25º N, at any given altitude. Aircrews who

regularly fly from North America to Europe and Asia routinely receive the highest exposures to in-flight cosmic radiation, which can be as high as 6 mSv or more per year depending on the combinations of the other variables.

- Length of time at altitude: Long flights at cruise altitude expose crews to more in-flight radiation versus short hops.
- Period during the 11-year solar cycle: The Sun follows a high to low then back to high level of flare activity which runs in an approximately 11-year pattern. When the Sun is in its' more active phase, less galactic radiation conversely reaches our planet.
- Solar flares: These events are sporadic, and can vary greatly in strength and degree of biological concern, boosting in-flight exposure levels by 10 times or more. Elevations in radiation levels that are induced by solar flares can last for a few minutes or a few days.

***Defining Your Exposure Risks***

Exposure to ionizing radiation is factually well established as causing cellular disruption and lifetime-cumulative DNA damage. The principal concern from DNA damage is a corresponding increased likelihood of developing cancer, and birth defects in the offspring and future generations of the exposed individuals. The statistical analyses of these risks and expected detrimental health effects are calculated to be relatively low. For the sake of brevity in this article, the statistical probabilities of incurring any of these risks are not outlined here, but these numbers are readily available (one source is the CAMI website at http://www.cami.jccbi.gov/radiation.html), and you should review them for your own edification. It is important to realize, however, that these probabilities are not based on actual cosmic radiation exposure studies. Instead, the risk estimation is based on mathematical models, calculated from linear interpolations backward from the high dose effects observed in the victims of the Nagasaki and Hiroshima bombings. The doses received by the bombing victims were, over the short term, much higher than any crewmember would ever incur. However the type of radiation from the bombs was actually of a lower type of energy and less destructive to DNA molecules than the high energy protons and neutrons that are the main exposure component for aircrew at jet cruising altitudes. Therefore, whether or not these mathematical models are indeed accurate risk probabilities remain to be seen in comparison to studies done on actual aircrew.

At the time the article "Aircrew Radiation Exposure" was published in *Flightline* (April/May/June 2000), too few studies on aircrew health issues had been completed to support any suspicions of increased health detriment. Now, however, trends are emerging in aircrew health that may be linked to radiation exposure. A variety of studies have shown increased rates of various cancers among pilots. [Note: Visit the link on the APA Aeromedical Committee web page for more detail.] Some of these results have been called into question within the scientific community because of the relatively small group of pilots that were observed. Despite this, there does seem to be growing evidence of higher rates of some types of cancers among pilots which can be linked to radiation exposure, particularly leukemia. Higher incidence of leukemia has long been associated with increased exposure from radiation.

One cancer trend among airline pilots that is quite strong is malignant melanoma, the most serious form of skin cancer. Malignant melanoma occurs in pilots at three to four times the rate observed in the general population. These excessive rates are not believed to be justifiable by "lifestyle factors" i.e. leisure time spent outdoors, nor, again, from UV radiation coming through aircraft windshields. Of interest is that the melanoma occurs in both commercial jet pilots as well as in lower flying (and lower cosmic radiation-exposed) commuter pilots. Therefore, it is questionable as to whether the significantly higher rates are from cosmic radiation, or may be due to electromagnetic radiation from the cockpit electronics, or perhaps even circadian rhythm disruption from back side of the clock schedules.

While debate continues as to the cause(s) of these different cancers, and additional studies are clearly needed, the evidence is already strong enough to warrant concern that in-flight radiation exposure has real health effects. Consequently, measures should be followed to minimize unnecessary exposure such as that from the rare—but potentially strong—solar flare. More about positive progress on that later in this report.

***Flying and Pregnancy***

An area of health concern where all the experts are in agreement is the matter of crewmember flying during pregnancy. Experts on this topic recommend that crewmembers do not fly during pregnancy unless their flying will be short hops, mostly at FL290 and lower, to keep from overexposing the fetus to radiation. For example, flying on transcontinental or European routes with a 75-hour flying month at cruising altitudes of FL350 or above, a pregnant crewmember is exposing the fetus to radiation that will likely exceed the recommended dose before the end of the first trimester. Fetal overexposure will occur on flights between the U.S. and Asia in the course of about one month. One long flight during a strong enough solar flare can result in enough exposure to reach the recommended maximum fetal dose in that one flight alone. The National Council on Radiation Protection and Measurements recommends that the dose to the fetus--considered the same as what the mother receives—not exceed 0.5 mSv over any one month period. The other recognized authority on radiation limits, the International Commission on Radiological Protection, limits exposure to no more than 1 mSv during the entire pregnancy.

Another important consideration is that flying during the first trimester is the most critical time for a fetus since this is when major organ development occurs. As a result of the rapid growth that the baby undergoes, it is very sensitive to the destructive power that radiation has on all rapidly growing cells. Since a baby's body is comprised completely of growing cells (and has fewer of them to start with), it is much more sensitive and easily harmed by radiation than an adult is.

Pregnant crewmembers who seek advice about flying during pregnancy need to be aware that a physician is, in most cases, *not* the best source of information on in-flight cosmic radiation exposure. Physicians are not trained on this issue in medical school and, more often than not, are uninformed of the hazard that frequent flying poses to a fetus. Obstetricians usually tell their pregnant frequent flier patients that as long as they feel well enough, it's permissible to fly. This is *not* what experts on in-flight cosmic radiation advise.

In Europe, pregnant air crewmembers, particularly with long-haul flying schedules, are grounded for the duration of their pregnancy once they report it, to minimize the risk of fetal overexposure. In the U.S., the crewmember must manage this issue on her own. Most radiation experts advise that a crewmember should take a medical leave of absence as soon as she learns of her pregnancy. For more guidance on this issue, she should review available information at:

- "AA Medical" link from aapilots.com
- Call-A-Nurse at (800) 555-2373
- Articles and links found on the APA Aeromedical web page under "Radiation"

***The Solar Flares of October 2003***

Solar activity that occurred in late October 2003 was noteworthy for it's strength and persistence. Fortunately, however, the Earth was not in the direct path of the trajectory of the flares, and so exposure levels to in-flight radiation were not as bad as they could have been if the Sun had taken better aim at our planet. Space weather scientists measure the strength of solar flare events on three different scales:

- G – Geomagnetic
- R – Radio
- S – Solar

Though the G and R categories can disrupt radio and electrical systems, they are not considered biologically harmful. The S flare scale is an indicator of in-flight health concerns, particularly for flares with strengths from S3 to S5, with S5 denoting the strongest radiation output. These ratings are explained in greater detail in a posting that the APA Aeromedical Committee recently issued, available on the APA Aeromedical Committee's Radiation web page.

When the news media first began reporting the October 2003 solar activity, the APA Aeromedical Committee was already monitoring the situation. The flares were strong in the G and R categories, but not in the biologically-sensitive S category. This information was reported to our pilots through APA Communications. Since solar flares are typically very dynamic events and often change rapidly in strength in any of the G, R, or S categories, close monitoring of the activity is essential to be able to determine if in-flight radiation levels may pose a health threat to occupants of commercial aircraft. Constant monitoring during solar flare events is difficult and problematic for aircrews. When solar radiation began to reach levels of biological concern on October 29, APA issued an email blast to the membership, attempting to notify as many pilots as possible so that those who may have been affected could coordinate with Dispatch to fly at lower altitudes. The blast email specified CAMI-recommended altitudes, based on their assessment of that specific event. The increased exposure levels lasted several hours, extending into the early morning hours of October 30, and then began to subside.

Once a significant solar flare event occurs, physicists who are experts on in-flight cosmic radiation calculate actual radiation levels that airborne individuals may have been exposed to during the event. They typically take a month or more after the event to gather the data from tracking stations all over the planet. Some of these are in very remote areas such as Antarctica and are manned irregularly. Once the information has

been collected, they can then do the appropriate math, defining the strength and location of radiation levels worldwide during that particular event. For those of you who may want to view these numbers and use them to calculate your own dose, look for them to be available on the CAMI web site in early January 2004.

***Promising Progress Has Been Made!***

Obviously, expecting aircrew to monitor solar changes in radiation levels during a solar flare event and to take corrective action on their own is not a very effective way of protecting crews and passengers from potentially significant radiation exposure. The need to constantly monitor radiation levels during a solar flare event to be able to respond accordingly had already been recognized and targeted by the APA Aeromedical committee several years ago. The committee saw that solar flare predictions and reporting needed to be improved and expedited.

APA, along with other interested parties, urgently requested that an effective reporting system be developed. Consequently, in January 2002, with the use of a new satellite that was specifically launched to enable such a system, the National Oceanic and Atmospheric administration (NOAA) and CAMI developed an early solar flare alerting system. With this new technology, detection of a solar flare that is strong enough to be of potential health concern takes place within minutes. The solar alert can then be transmitted in real time to the airline, similar to how they currently receive weather airmets and sigmets. The solar alert would also include the maximum recommended altitude that aircraft should observe to avoid harmful exposure for its occupants. Unfortunately, a confluence of events at AA stalled the implementation of the solar alert system, making it a low priority: AA's administration in place at the time, the difficulties from 9/11 and resulting financial devastation experienced by the industry, and the crash of Flight 587.

A meeting was arranged for November 4, 2003 with new Vice President of Flight, Captain Mark Hettermann, to renew attempts to have the solar alert system implemented at AA. Although the October solar activity occurred before our scheduled meeting, it did provide the unintended effect of adding credence to the necessity of the alert system. Captain Hettermann was receptive to implementing the plan. As a result, two working groups comprised of APA, APFA, AA Medical, Flight, Safety, SOC and Flight Service have been formed to develop a specific plan of action to deal with in-flight radiation exposure, and avoid excessive exposure during future solar flare events. The working groups have already addressed the following specific issues:

- Implementing The Early Solar Alerting System: As of November 2003, the alert system is in the process of being installed at AA.
- Altitude Capping: When the possibility of a solar flare appears likely, overwater international flights without the option of an easy change in altitude will be dispatched at a max altitude of FL310 in flight regions at 35º N and above, or 35º S and below. Fuel options will be provided to go lower if the event actually occurs and if proper clearance can be obtained.
- Lowering Latitude: In addition, if an event is already in progress, flights will be planned at lower latitudes to destination whenever possible. The necessity of fine-

tuning planned cruise altitude to an even lower altitude will be considered. Coordination between Dispatch and pilots is encouraged.

- Flight Plan Messaging: If a flight has been planned at a lower altitude due to solar activity, a message informing the crew that the lower altitude is due to solar activity will be on their flight plan when they pull it up in Ops.
- ACARS Messaging: If a solar event occurs after a flight has already left the gate, an ACARS message will be sent to crews along with advice on any need for altitude change.
- Additional Fuel For Non Over-Water Flights: If any changes in solar activity are expected and descent would be desirable with that event, Dispatch will allow more fuel for that option.
- Better Training: Both pilots and flight attendants will be given more detailed information on in-flight radiation and operations during solar flare activity. Health concerns from exposure to cosmic radiation and special considerations for pregnant crewmembers will be addressed and information provided to both work groups.

***Concluding Comments***

**It is very important for pilots to realize that any changes in flight operations due to solar activity are not emergency procedures**. Altitude changes or any other change in flight plan due to solar activity should only be done with proper clearance from ATC, and only if fuel, weather, and other considerations safely allow it. Changing altitudes to avoid radiation exposure should never cause a more imminent hazard than it was attempting to prevent!

Details of this new plan of action will be issued by AA and should not be considered official until then. In the meantime, and always, aircrew should feel free to monitor the web sites and hotlines provided below to stay apprised of solar activity. You should discuss any related concerns with your dispatcher or Chief Pilot. APA will also continue to pass on relevant information to the membership as the situation warrants.

This development with AA represents a major accomplishment in effectively managing in-flight cosmic radiation exposure for our crewmembers. It heralds an encouraging commitment by American to work with APA and its other employee groups to solve problems in a manner beneficial to both parties. Such cooperation is vital for keeping a company at the top of its game and at the head of the pack. With these measures underway at American, other airlines will follow our lead; their passengers and employees will be posing difficult questions to them if they do not. Solar flares do not occur often, and operational adjustments at AA will be infrequent. The cost for implementing an early solar alert system should be recognized as being well justified and necessary to safeguard the health of our employees and passengers.

Recommended Radiation Websites and Resources

- Solar Flare Events:

  www.sec.noaa.gov
  Http://www.cami.jccbi.gov/radiation.html
  Hotline: (303) 497-3235

- Calculating In-Flight Doses:
  http://www.cami.jccbi.gov/radiation.html
- Information On Pregnancy and Flying:
  AA Medical Website, through aapilots.com
  AA Call-A-Nurse (800) 555-2373
  APA Aeromedical Webpage at www.alliedpilots.org, “Radiation”
- Educational Information On In-Flight Radiation:
  www.alliedpilots.org, “Radiation”
  www.sievert-system.org
  www.cami.jccbi.gov/radiation.html
  AA Medical Website at aapilots.com

References

References:

Boice JD, Blettner M, Auvinen A. Epidemiologic Studies of Pilots and Aircrew. *Health Phys 2000*; 79:576-84

Friedberg W, Copeland K, What Aircrews Should Know About Their Occupational Exposure to Ionizing Radiation. FAA, Office of Aerospace Medicine, Report No. DOT/FAA/AM-03/16 October 2003.

National Oceanic and Atmospheric Administration Website:
http://www.sec.noaa.gov

FAA Civil Aeromedical Institute Website:
http://www.cami.jccbi.gov

Barish, RJ. The Invisible Passenger. *Advanced Medical Publishing, P.O. Box 532 Sun Prairie, WI, 1996*

Friedberg W, Snyder L, Faulkner DN, Darden EB Jr. and O'Brien K, Radiation Exposure of Air Carrier Crewmembers II. FAA, Office of Aviation Medicine, Report No. DOT/FAA/AM-92-2

Nicholas JS, Copeland KA, Duke FE, Friedberg W, O'Brien K, Galactic Cosmic Radiation Exposure of Pregnant Flight Crewmembers. *Aviation, Space, and Environmental Medicine*, Vol. 71 No. 6, June 2000.

Bailey S. Air Crew Radiation Exposure-An Overview. *Nuclear News*, January 2000.

Sinclair WK, Radiation Protection Issues In Galactic Cosmic Ray Risk Assessment. *Advances in Space Research*, Vol.14, 1994 COSPAR.

Hendee EWR, Edwards FM, Bowie C. Health Effects of Exposure To Low Levels of Ionizing Radiation, *British Medical Journal*, 314 (7076): 313-314, 1997

May JA, Standifer R. Aircrew Radiation Exposure. *Flightline April/May/June 2000.*

http://www.sievert-system.org