IFALPA
The Global Voice of Pilots

Medical Briefing Leaflet

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Cosmic Radiation

Background

At its 2012 conference in Paris, IFALPA adopted its new policy on cosmic radiation. The solar cycle is now moving into a period of increased activity, with the activity peak estimated in 2013. Therefore, there is a need for this medical briefing leaflet on cosmic radiation to educate our membership.

Cosmic Radiation

Cosmic radiation (CR) originates from deep space (constant intensity), it is referred to as background Cosmic Radiation or Galactic Cosmic Radiation (GCR), and from the sun (intensity increases with solar flare activity), referred to as Solar Radiation. CR consists of a comprehensive spectrum of particles and electromagnetic radiation. Cosmic rays can have energies far in excess of manmade radiation sources. Since radiation shielding[1] is based on the interaction of the radiation with matter, the shielding of CR in the higher atmosphere is less than at surface level. Earth's magnetic field and the sun's magnetic field (magnetosphere) partially protect Earth from charged particles in the CR. As some of the CR components are very penetrative, shielding of aircraft against it is impracticable. Thus, the dose rate resulting from CR depends on the latitude, altitude, and solar cycle.

Latitude

Generally speaking, Earth's magnetic field is weakest at the magnetic poles, and therefore the cosmic radiation levels are higher in the polar regions and decline towards the equator.

Altitude

The larger the mass of atmosphere above, the better it protects aircrew from radiation. Commercial aircraft altitudes are typically FL200 to FL390, where dose rate double for every 6,000ft of increased altitude.

Solar Cycle

The sun goes through a solar cycle of about 11 years. This is due to the sun's varying magnetic field, which is determined by interior Sun activity. A Solar cycle can be detected from the number and frequency of sun spots. At the solar minimum, there are only a few sun spots, and at the solar maximum vice versa. At the solar minimum, the amount of radiation is up to 100% (the double), and this is because the Cosmic radiation effects have less modulation due to reduced Solar activity. At the solar maximum, the converse is true, in that whilst we may have potentially high-energy solar particle events occurring, the general increased solar activity acts as a shield, reducing the background Cosmic component. Hence at the solar maximum, there is the possibility for solar storms, which may lead to short-term increases in radiation levels.

Solar Storms

Solar storms form when there is explosive release of magnetic energy from the sun into space in the form of solar flares and Coronal Mass Ejections (CME). Solar flares are the eruptions from the sun's surface and a CME is an eruption of a large volume of the sun's atmosphere. Usually, they are of insufficient energy to contribute significantly to the radiation field at aviation altitudes. However, on occasion, the energy reaches Earth and a sudden increase in radiation level can be experienced (Ground Level Event (GLE)). The duration of such a GLE ranges from hours to a few days.

1. It depends on the type of the radiation, on the radiation energy and on the properties of the shielding material (density, atomic number, etc.).

The effects of solar storms

Solar storms can cause the loss or degradation of Radio Frequency (RF) communications and satellite navigation signals. This can occur in the absence of excessive ionising radiation levels at commercial flight altitudes. Similarly the Aurorae Borealis and Australis (Northern and Southern lights), while resulting from the interaction of charged particles with air in the upper atmosphere, may be an indication of increased ionizing radiation levels at flight altitudes.

Occasionally, solar storms cause a GLE. However, at the same time there may be a significant decrease in the level of background cosmic radiation (Forbush decrease). The extra doses of radiation caused by GLEs are usually less than 100µSv. During the last 60 years, there have been five solar storms where the radiation dose would have exceeded 1 mSv during a cross-Atlantic flight. This is also approximately equal to the radiation dose received from three months of commercial airline flying.

Doses of cosmic radiation

Ionising radiation can be objectively measured by absorbed dose: the energy deposited per unit mass. The absorbed doses of different types of radiation cause different biological effects, and sensitivity of different body tissues to these different types of radiation varies. Therefore, tissue-absorbed doses are multiplied by radiation weighting factors to give equivalent doses, and by tissue weighting factors to give the effective dose. The unit of the equivalent dose and the effective dose is called Sievert (Sv) and it allows a comparison between the health effects of different types of radiation.

Some examples of radiation doses and dose rates

As we do not come across general radiation dose issues in daily life, it is sometimes hard to comprehend the magnitude of different radiation doses. In figure 1, you can find some examples of doses that might help clarify the magnitude of exposure. The additional annual cosmic radiation dose that aircrew generally receive is 2-5 mSv.

Figure 1: Radiation dose vs. source

Radiation Dose	**Source**
0.01 millisievert (mSv)	Tooth X-ray
0.06 mSv (60 µSv)	Flight HEL-NRT (approx. 9 hrs flight time)
0.1 mSv (100 µSv)	Chest X-ray
1 mSv	Annual dose limit for the public
2-5 mSv	Annual cosmic radiation dose for flying personnel
3.7 mSv	Average annual Finnish radiation dose (background radiation, indoor radon, medical radiation, etc.)
20 mSv	CT scan
20 mSv	Limit on effective dose for occupationally exposed workers averaged over defined periods of 5 years, with no single year exceeding 50 mSv
500-1000 mSv	Dose required for acute radiation illness
4000 mSv	Lethal dose when received at once
Some examples of doses rates (doses/hour)	
0.04-0.30 µSv/h	Natural background radiation in Finland
5-8 µSv/h	FL 260-390 in temperate latitudes [UNSCEAR 2000]
10 µSv/h	Some protective measures are needed, e.g. avoiding being outdoors [2]
30 µSv/h	The dose rate measured at a distance of one metre of a patient that has undergone isotope treatment. When the dose rate is less than 30 µSv/h, the patient can be discharged.[3]
100 µSv/h	It is necessary to take protective measures, e.g. to take shelter indoors [4]

Dose estimation and onboard dosimeters

There are various computer code programs that have been developed around the world, that basically apply the concepts discussed earlier, namely latitude, altitude, and the Earth's heliocentric potential (Magnetosphere) shielding to provide an estimate of radiation dose. In Europe, the common code used is EPCARD, in Canada they use PCAIRE and the FAA developed a code, CARI-6, for general use.

These codes provide a method of determination of dose estimate based on flight-planned routes. Furthermore, during increased solar activity such as Solar Maximum, the codes need to be modified post-event to allow for the increased doses, which are not uniform globally for similar altitudes and latitudes.

The advent of several world-class radiation monitors in recent years that accurately record the ambient dose equivalent radiation, now enables aircrew to proactively apply judgement in the case of such alerts being issued from the National Oceanic and Atmospheric Administration (NOAA).

Current IFALPA policy requires an ICAO lead task-force to evaluate the possible descent procedures for a large number of aircraft in the event of a solar storm and unless sound airmanship dictates such descent, then we believe crew should not descend before this evaluation has been completed. However, during flight planning, the use of lower FL can be considered in case of solar storms.

Feasible, compact onboard monitors are reaching market. They can measure the whole range of radiation and provide a more accurate dose reading than mathematical models. The principle of measurement over estimation is valid in radiation protection. When available, their use is encouraged.

2. cf. http://www.stuk.fi/sateilyvaara/en_GB/esim_annos/
3. cf. http://www.stuk.fi/sateilyvaara/en_GB/esim_annos/
4. cf. http://www.stuk.fi/sateilyvaara/en_GB/esim_annos/

Low dose radiation protection

There are three fundamental principles in radiation protection[5] :

- Justification
- Optimisation
- Application of dose limits

Regarding justification there is no doubt that the decision for aviation and for the affiliated modification in radiation exposure does more good than harm. Optimisation signifies that the likelihood of incurring exposure, the number of people exposed and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economical and social factors (ALARA-Principle). The result of this principle for aviation is, that flight planning and flight performing shall be optimised in respect to radiation exposure but also under socio-economic considerations. Application of dose limits means that the total dose to any individual should not exceed the appropriate limits specified by the ICRP.

There are two methods of dose radiation protection: either radiation shielding or applying dose constraints. Disregarding the shielding by the atmosphere, it is impractical to shield aircraft effectively from cosmic radiation. Therefore, the most viable option for flight crew is dose constraints/limits.

ICAO and authority requirements

ICRP

The International Commission on Radiological Protection (ICRP) is the primary body in protection against ionizing radiation. ICRP is an independent ,non-governmental organization formed to advance, for the public benefit, the science of radiological protection. The ICRP provides recommendations and guidance on protection against the risks associated with ionising radiation, but has no binding power. However, most of the authority rules adhere to ICRP recommendations.

ICRP acknowledges aircrew to be occupationally exposed to radiation. The recommended effective dose limit is 20 mSv per year, averaged over defined 5-year periods (100 mSv in 5 years), with the further provision that the effective dose should not exceed 50 mSv in any single year. In addition, the recommendation for pregnant crewmembers is 1mSv from declaration of pregnancy for the remainder of the pregnancy. For the general public (e.g. passengers) the annual limit is 1mSv.

ICAO Annex 6

ICAO Annex 6 6.12 requires all airplanes intended to be operated above 15,000m (49,000ft) to carry equipment to measure and indicate continuously the dose rate of total cosmic radiation being received and the cumulative dose on each flight. ICAO Annex 6 4.2.11.5 requires the operator to maintain records of flights above 15,000m (49,000ft) so that the total cosmic radiation dose received by each crew member over a period of 12 consecutive months can be determined.

European authority requirements

There were some requirements concerning radiation detailed in EU-OPS 1.390, but these were deleted from the new EASA part OPS as regulation concerning radiation is in a separate EU directive (Council Directive 96/29/Euratom). This was to prevent overlapping of regulations. However, the EU directives concerning radiation are to be amended, and there is already a draft for a new directive (Euratom Basic Safety Standards Directive). Most likely there will be some changes to the current regulation, but the timeline for the new directive is not known at the moment. In addition, each state in Europe may have, and quite few have, more strict national legislation concerning radiation. Usually, this national legislation restricts the annual radiation dose from occupational exposure of cosmic radiation to 6 mSv.

Council Directive 96/29/Euratom (article 42)

The limit on effective dose for exposed workers shall be 100 mSv in a consecutive five-year period, subject to a maximum effective dose of 50 mSv in any single year. For pregnant women there is a maximum dose of 1 mSv during the remainder of the pregnancy. In addition, there are a few requirements for crew who are liable to be subject to cosmic radiation exposure of more than 1 mSv per year:

- to assess the exposure of the crew concerned,
- to take into account the assessed exposure when organising working schedules with a view to reducing the doses of highly exposed aircrew,
- to inform the workers concerned of the health risks their work involves,
- to apply Article 10 to female aircrew.

FAA regulations

There are no binding regulations concerning radiation within FAA rules. However, the FAA considers aircrews to be occupationally exposed to ionising radiation and has the same recommended limits as ICRP recommendations, i.e. a 5-year average effective

5. ICRP 103: Executive Summary (o)

dose of 20 mSv per year, with no more than 50 mSv in a single year. For pregnant crewmembers, starting when the pregnancy is reported to management, the recommendation is 1mSv limit for the remainder of the pregnancy.
IFALPA recognises 20 mSv as the annual limit for occupational exposure for airline flight crews as established by the ICRP in Recommendation 103 (2007). In addition, in most of the European countries, there is an additional 6 mSv annual constraint for occupational exposure of cosmic radiation.

Cosmic radiation and cancer risk in pilots

Does a commercial pilot's occupational exposure to ionising radiation result in any long-term adverse health effects?
The International Commission on Radiological Protection (ICRP) acknowledged the occupational radiation exposure for flight crew in 1990, which resulted in renewed research interest into this topic. Over the last 20 years, there have been more than 65 epidemiological studies published in scientific literature that investigate flight crew and cancer risk. This figure includes a number of reviews and meta-analyses.

Overall cancer risk was not elevated in most studies and subpopulations analysed, while malignant melanoma, other skin cancers and breast cancer in female aircrew have shown elevated incidence, with lesser risk elevations in terms of mortality. In some studies, including the large German cohort, brain cancer risk appears elevated. Cardiovascular mortality risks were generally very low. No clear-cut dose–response patterns pointing to a higher risk for those with higher cumulative doses were found. Overall, aircrew are a highly selected group with many specific characteristics and exposures that might also influence cancers or other health outcomes. Radiation-associated health effects have not been clearly established in the studies available so far[6] .
However, it is certainly worth noting that whilst the annual exposure of other radiation workers (e.g. nuclear workers, medical and industrial radiographers, etc.) is decreasing following the introduction of the principle to reduce doses 'as low as reasonably achievable', radiation doses of airline flight crew do continue to increase, as advances in aerospace technology permit longer duration, higher altitude, and higher latitude flights. Many of the epidemiological studies are ongoing and further information can be expected.

IFALPA policy on cosmic radiation

A new IFALPA policy on cosmic radiation was accepted at the IFALPA annual conference 2012. Members can access the entire IFALPA policy in the members area of the IFALPA website (IFALPA Technical Manual, Annex 06, Section 6.12). The major amendments were:

- Flight personnel with an effective dose of more than 1 mSv/y should be recognised as occupationally exposed to ionizing radiation. Those who are liable to receive an effective dose greater than 6 mSv per year should be classified as Category A workers.
- All aircraft with a maximum operating altitude of more than 8,000m (approx. 26,000ft) operating in polar/sub polar regions, especially long-range aircraft, should be equipped with a warning device to detect sudden increases in dose rate. During flight, the cockpit crew should have the display of the warning function plainly visible to allow timely response to suddenly increased levels of dose rates.
- IFALPA recommends that an ICAO sponsored multi-party task force be formed to address all issues associated with an ionizing radiation event and the possible subsequent emergency descent of a large number of aircraft.

Radiation has been and will be affecting pilots always. It is one occupational risk factor among others, but fortunately the risk for health effects, with our current knowledge, is very low. Despite of this, IFALPA will continuously follow up on all radiation studies. Timely and more accurate knowledge on the magnitude of the health risks from radiation is being gathered all the time.

6. Hajo Zeeb , Gael P Hammer, Maria Blettner, Epidemiological investigations of aircrew: an occupational group with low-level cosmic radiation exposure, J. Radiol. Prot. 32 (2012) N15–N19