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Cosmic radiation dosimetry on board an aircraft: the SIEVERT system

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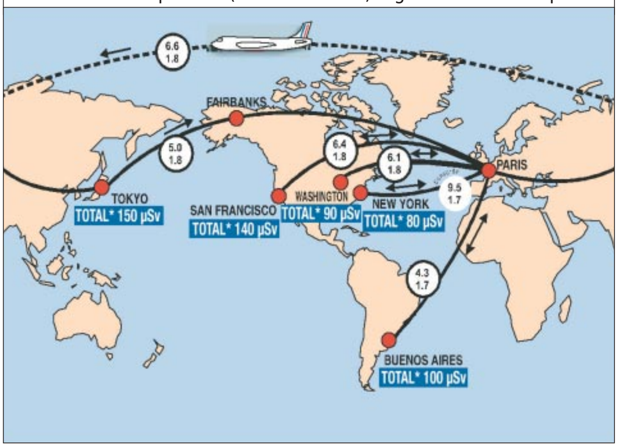
Cosmic radiation doses received on board an aircraft are higher than on the ground. Flight crews can receive an effective dose of several millisieverts per year as a result of their occupation. In the light of that, European regulations adopted in 1996 oblige aircraft operators to monitor the exposure of their flight crews. A tool, the SIEVERT system, has been developed in France to meet this requirement.

Aircraft cruising at an altitude of about 10,000 m.

Figure 1

Doses received during different flights obtained from measurements taken between 1996 and 1998 with NAUSICAA apparatus.

The circles show the mean dose equivalent rate for the flight (µSv/hr) and the mean radiation quality factor (equivalent dose: absorbed dose ratio). The total dose equivalent (mean rate x time) is given for a round trip.



Cosmic radiation exposure in planes

Exposure increases with altitude

As altitudes get higher, the atmosphere's protective layer becomes more rarefied and cosmic radiation exposure gradually increases. Cosmic radiation at airline cruising altitude, that is at 10,000–12,000 m, is 100–300 times more intense than at sea level. On board Concorde, which flies at 18,000 m, the dose rate is almost double that on board a subsonic aircraft.

Latitude affects exposure levels

As the earth's magnetic field creates a barrier, cosmic radiation particles penetrate more easily at high latitudes close to the poles than they do close to the equator. Radiation exposure will depend on the latitudes of the route taken by the aircraft. Measurements taken on board long-haul aircraft in the 1990s (**figure 1**) have shown that the flight crews receive annual effective doses in the range 2-5 mSv that vary with the routes flown and solar activity cycles.

The SIEVERT project

European regulations adopted in 1996 oblige aircraft operators to monitor the exposure of their flight personnel (**box**, page 124). The French authorities have set up SIEVERT, the computerized system for assessing cosmic radiation exposure during air transportation. This dose assessment tool has been developed by the French civil aviation department (DGAC) and its partners, the Institute for Radiological Protection and Nuclear Safety (IRSN), the Paris Observatory and the French Institute for Polar Research - Paul Emile Victor (IFRTP).

IRSN acts as a dosimetry expert to provide and regularly verify monthly cosmic radiation dosimetry data. The Institute houses the SIEVERT system and is responsible for running it.

Assessing radiation doses received during flights

Airlines can make use of the SIEVERT system to help them follow the recommendations made in ICRP publication No. 60 and apply article 42 of the European Directive EURATOM 96/29. This business-dedicated service is available on an Internet server that can be accessed by firms who have applied to the DGAC for authorization. Ordinary passengers can also access it to estimate the dose received during a flight.

Figure 2

Principle of data exchange between SIEVERT and the airlines.

Members of the public can assess the dose received during one or more flights by getting onto the SIEVERT site (http://www.sievert-system.org). This assessment is made from the data available on the flight ticket (**figure 3**).

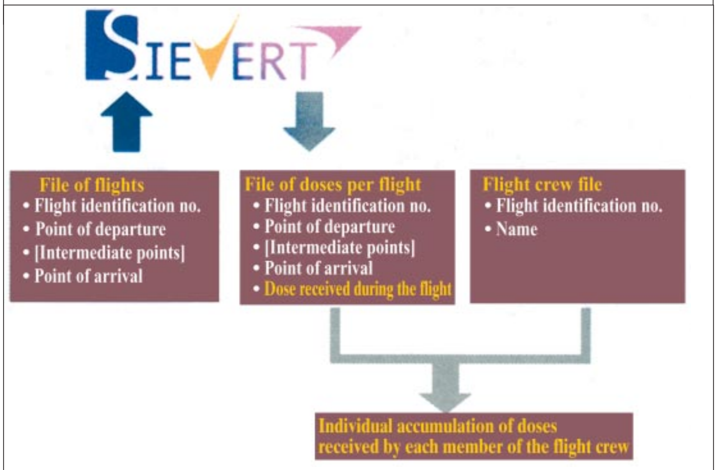
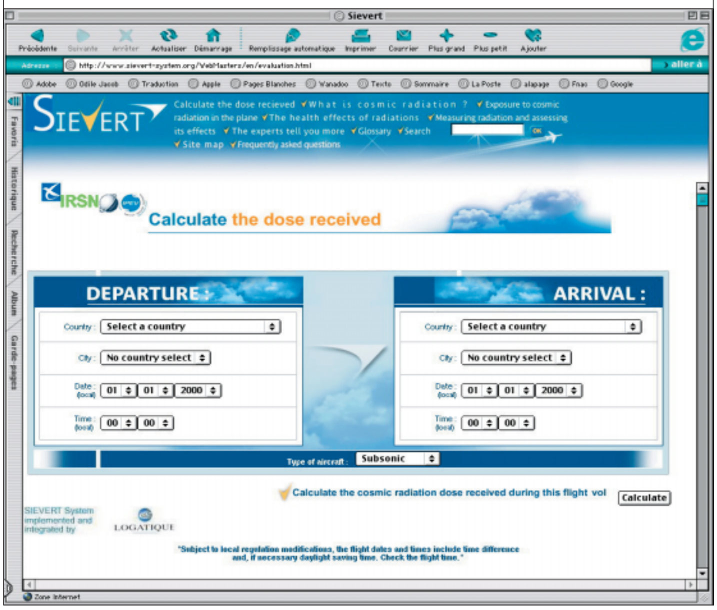


Figure 3

Data input mask for the general public.



The system calculates the dose using the flight parameters. These values are calculated from dosimetry models that have been verified over several tens of flights. Furthermore the SIEVERT system can assess the impact on the dose received in the event of a solar eruption.

SIEVERT is a tool dedicated to aircrew dosimetry. The airlines do not require any special radiological protection skills to use it and in contrast to personal dosimeters, the flight crews are not in any way encumbered by using it. There are two good reasons why SIEVERT will lead to proper implementation of the regulation. First of all, the results obtained are reliable and validated. Secondly, the dose assessment method is the same for all airlines.

Sievert usage principle

The airline creates a file of completed or planned flights and leaves it at the SIEVERT Internet address. The system then fills in the file by adding the effective dose for each flight (**figure 2**). The dose is calculated in line with the flight characteristics, on the basis of dosimetry input data validated by IRSN. The fuller the detail provided on the flight path, the more accurate calculation of the dose will be. If the information is minimal, the dose value will be assessed from a standard flight profile. At this stage the data is anonymous. It is then up to the employers to cumulate the doses received during the journeys made by each member of their flight staff. This information is made available both to the individual employees, the occupational physician and the national registry.

Calculating doses using Sievert

At the heart of SIEVERT, airspace is meshed, each grid cell being 1000 feet in altitude, with a longitude of 10° and a latitude of 2°. It forms a map of 265,000 cells all told, each of which is assigned an effective dose rate. Calculations are made of how long the aircraft spends in each cell and the corresponding dose (**figure 4**). They are added together to give the total dose for the flight.

Updating dosimetry data

The dose rate map is updated every month by IRSN to incorporate solar activity cycles (**figure 5**). This mapping is obtained from a computer code (currently CARI 6, developed by the Federal Aviation Administration) that can obtain the dose for any point in space up to an altitude of 80,000 feet. Regular radiation measurements are made with dosimeters installed on the ground and in the aircraft and enable the obtained values to be confirmed or corrected as needed. A specific map is generated in the event of a significant solar eruption, and then validated. The Paris Observatory astrophysicists are then called in to assess the impact of the solar eruption. It takes rather a long time to complete this complex study. So several weeks will have to elapse before calculations can be made of the doses received during flights at the time of the eruption.

The first results

IRSN worked on calculations of real magnitude in cooperation with Air France during the regular service audit (VSR) phase, before the service came on stream. Several tens of thousands of real flights were processed.

First statistics

A statistical study of these first results enabled a number of parameters to be validated, especially those assumed for standard flight profile definition used for the public when the real profile is unavailable. These first results demonstrate, apart from anything else, that there is wide dispersion on a dose for a given destination (up to a factor of 1.7), since environmental factors such as weather conditions can affect flight duration. In the interests of keeping on the safe side, the standard profile values obtained are generally towards the top end of the dose range for a given route (**figure 6**).

Validating the model in the event of a solar eruption

On 15 April 2001 dose measurements were taken for the first time throughout a Prague-New York flight during the course of which a solar eruption occurred that was perceptible from the ground (**figure 7**). These measurements were obtained by F. Spurny (Czech Academy of Sciences) as part of a European joint contract involving seven institutes, including IRSN. These types of events, called *Ground Level Event*s (GLE), occur at the very most a few times a year. This provided the opportunity to validate the dosimetry model set up in SIEVERT in the event of a solar eruption. The model is based on particle attenuation in the

Figure 4

Principle used in SIEVERT for calculating flight dose.

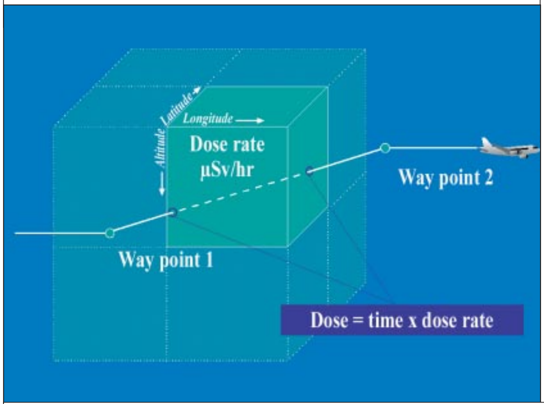


Figure 5

The various input data requirements for SIEVERT calculations.

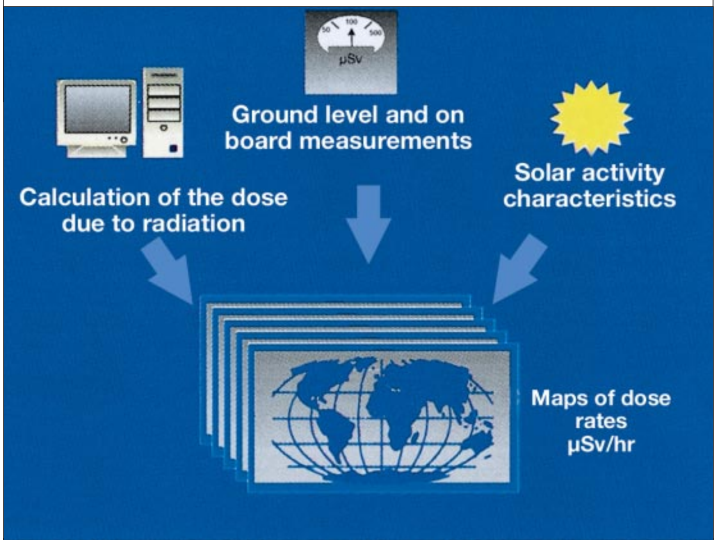
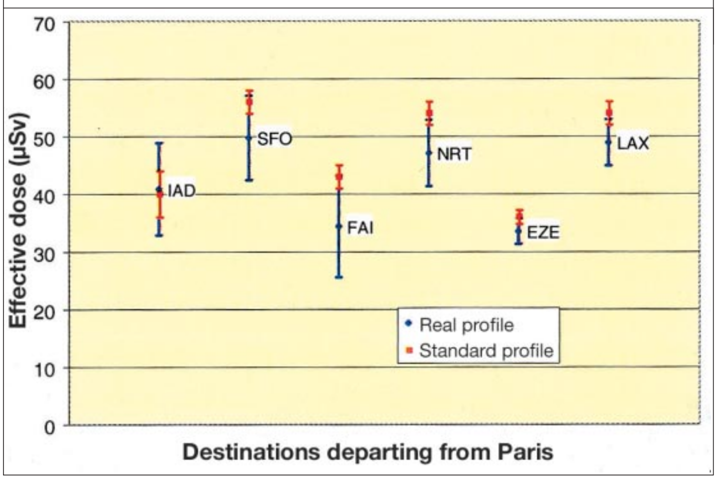


Figure 6

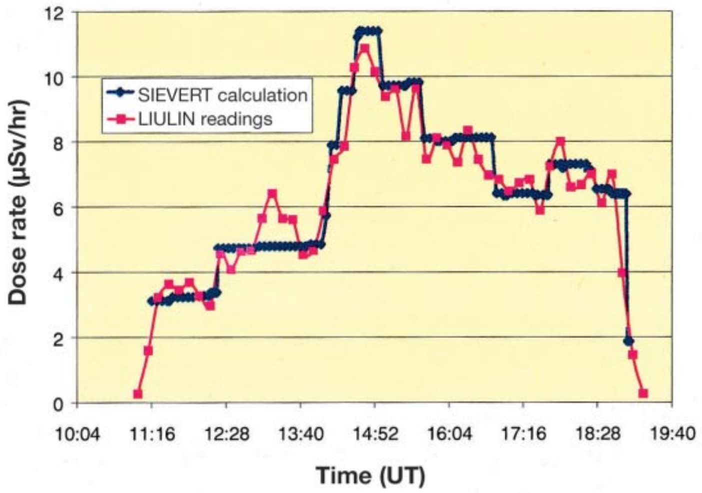
Comparison of the doses obtained with a set of real and standard flights for different routes departing from Paris over a one-month period (IAD: Washington, SFO: San Francisco, FAI: Fairbanks, NRT: Tokyo, EZE: Buenos Aires, LAX: Los Angeles).



atmosphere with energy comparable to that of solar eruptions and on data from ground-based neutron monitors that give the GLE intensity readings.

Figure 7

Profile of the dose rate measured with the aid of the "LIULIN" detector (semi-conductor detector), computed by SIEVERT for a Prague-New York flight on 15 April 2001 during GLE 60 that started at 1409 hours UT.



Summary

This working tool satisfies the demand made by airlines seeking radiological protection for their flight crews. Moreover it offers any individual who so desires, the possibility of assessing the dose received during a flight. SIEVERT is innovative in that statutory dosimetry is performed only from model-based calculations that have, of course, been validated by experience.

Of the various systems in operation around the world, SIEVERT is the first to have taken into account all the operational constraints of the aircraft operators and those relating to statutory dosimetry. Foreign companies have already shown interest in using this sort of system.

> THE REGULATION

The European directive EURATOM 96/29 dated 13 May 1996 modified the safety standards for protecting the health of the population and workers from the dangers arising from ionizing radiation. It was transposed into French law by the publication of order No. 2001-270 dated 28 March 2001, which should be completed by the publication of five decrees.

One of the innovations of this European directive is the extension to cover exposure to natural radiation. Article 42 makes the following provisions for the protection of flight crews:

"Each Member State shall make arrangements for undertakings operating aircraft to take account of exposure to cosmic radiation of air crew who are liable to be subject to exposure to more than 1 mSv per year. The undertakings shall take appropriate measures, in particular:

- *to assess the exposure of the crew concerned;*
- *to take into account the assessed exposure when organizing 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 air crew."*

Article 10 of the directive makes special provisions for protection during pregnancy. As soon as a nursing woman informs the undertaking of her condition she shall not be employed on airborne duties if the equivalent dose received by the unborn child is likely to exceed 1 mSv.