Results of the EAN request on radiation protection of aircraft crew
December 2010 - January 2012

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Questions sent to the members of the Network:

1. Is there a regulation concerning radiation protection requirements for aircraft crew in your country?

2. If yes:

- *What are the main requirements?*
- *What are the means and tools used to assess aircrew's exposure?*
- *Is there a specific dose criteria defined for aircraft crew?*

3. Could you provide data on the number of aircrew exposed, maximum annual level of exposure, average annual level of exposure, etc.?

SYNTHESIS

1. Countries answering the request

14 countries answered the request about radiation protection of aircraft crew: Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Lithuania, Slovenia, Sweden, the Netherlands and the UK. There is not a regulation concerning radiation protection requirements for aircraft crew in Norway.

2. Regulations

The regulations on radiation protection of aircraft crew are national regulations for every country answering the survey except for Sweden, which has implemented the international recommendations JAR-OPS 1.

For most regulations, the main requirements are the following, for exposure higher than 1 mSv a year:
- Assess exposure of the crew
- Take into account the assessed exposure when organizing flight schedules
- Inform the workers on risk due to cosmic radiation
- Limit the exposure of pregnant workers

Some countries add several requirements such as monitoring (Finland, France), medical surveillance (France). Specific requirements (protection actions) are implemented for exposure higher than 6 $mSv.y^{-1}$ in Belgium, Denmark, Finland, Germany, Ireland, Lithuania, Slovenia and Greece. In Slovenia a dose constraint of 2 $mSv.y^{-1}$ is implemented.

Furthermore, in Italy and in the Netherlands, aircrew flying regularly over 8 000 m (exposure higher than 1 $mSv.y^{-1}$ are category B workers).

3. Data

The Figure 1 below presents the data concerning the number of aircraft crew exposed and the Figure 2 the associated annual effective dose (both average and maximum) when available.

The number of aircrew exposed varies from 213 in Lithuania to about 40,000 in Germany and the UK. Concerning the maximum annual effective dose, the highest dose are about 6 to 8 mSv for Denmark, Germany and Finland and the lowest is about 1.7 mSv in Slovenia. The average annual effective dose varies from 1 mSv for Czech Republic to 2.5 mSv for both Finland and Sweden.

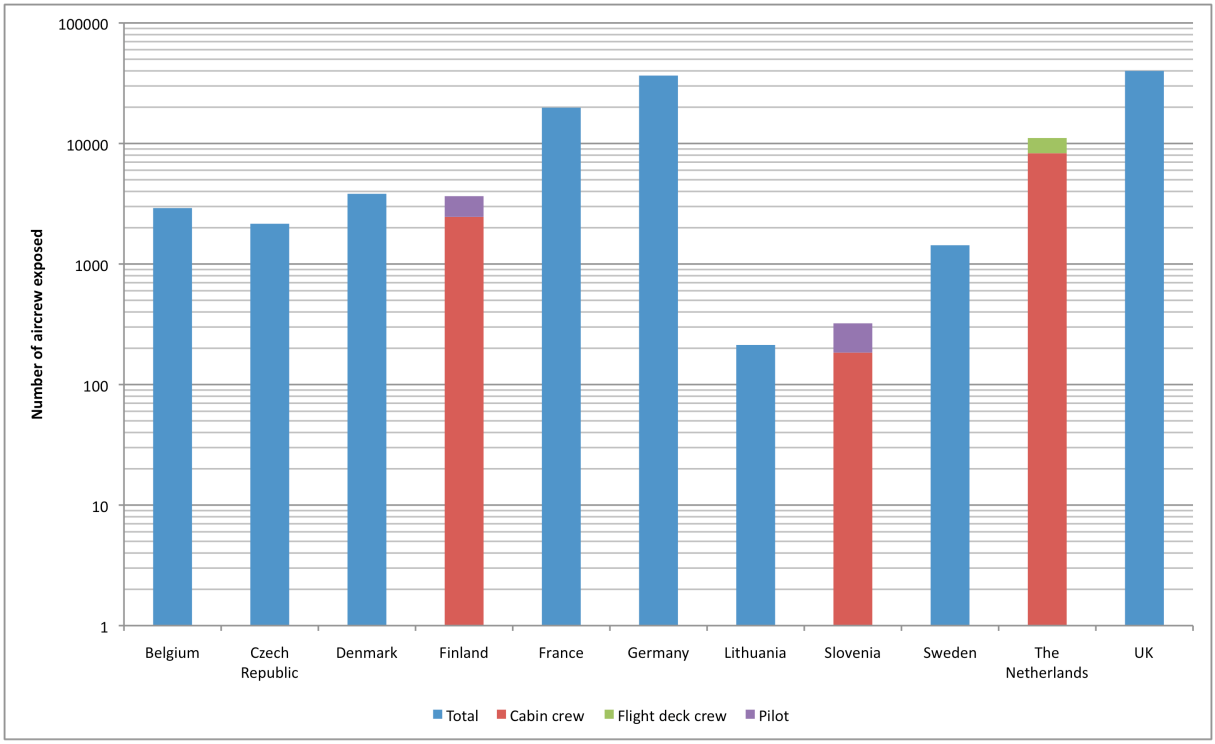


Figure 1. Number of aircraft crew exposed

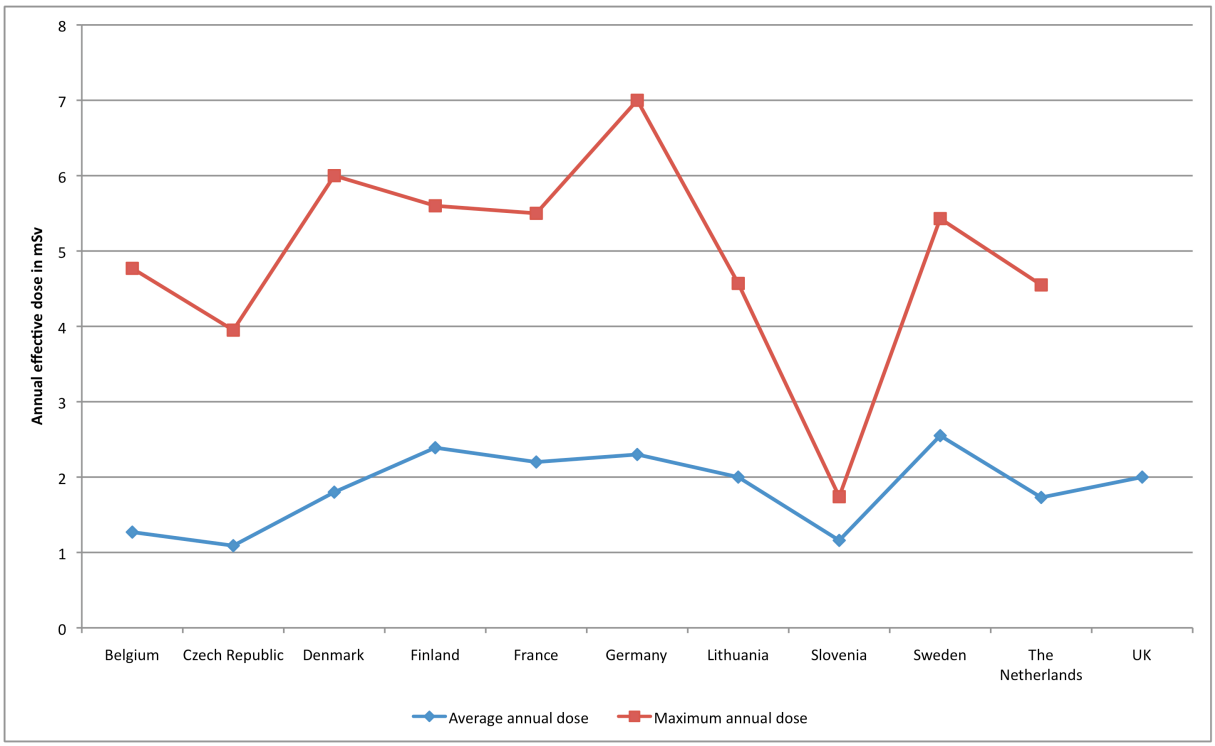


Figure 2. Average and maximum annual effective dose

Regulations

Country	Regulation	Main requirements	Assessment of exposure	Dose criteria
Belgium	Royal Decree of July 20, 2001 § 4 and 9	If exposure can be higher than 1 mSv in a year: - Assess exposure of the crew - Take into account the assessed exposure when organizing flight schedules - Inform the workers on risk due to cosmic radiation - Limit the exposure of pregnant workers.	FANC guidance defines 3 criteria to readily assess whether aircrews are unlikely to receive more than 1 mSv/y. If these criteria does not apply, assessment using one of the following software: IASON-FREE, PCAIRE, CARI or GLOBALOG	Dose assessment if the individual dose is higher than 1 mSv/y. No other specific criteria in theory. In practice special requirement is the dose is higher than 6 mSv/y.
Czech Republic	Regulation No. 307/2002 Coll. on radiation protection	If exposure can be higher than 1 mSv in a year: - Assess exposure of the crew - Take into account the assessed exposure when organizing flight schedules - Inform the workers on risk due to cosmic radiation - Limit the exposure of pregnant workers.	Assessment with CARI-6 software	/
Denmark	Guidelines on the Control of Exposure to Cosmic Radiation of Aircrew in the Nordic Countries	If exposure can be higher than 1 mSv in a year: - Assess exposure of the crew - Take into account the assessed exposure when organizing flight schedules - Inform the workers on risk due to cosmic radiation - Limit the exposure of pregnant workers.	Assessment with computer code: EPCARD, CARI-6, FREE	Specific requirements if > 6 mSv/y

Country	Regulation	Main requirements	Assessment of exposure	Dose criteria
Finland	Radiation Act 1991/592 - Chapter 12 Radiation Decree 1991/1512 - Chapter 7 Guide ST 12.4 - Radiation safety in aviation	If exposure can be higher than 1 mSv in a year: - Exposure must be monitored and assessed doses announced to the Dose Register, - Work shifts and flight routes must be planned to ensure that the worker's annual effective dose does not exceed 6 mSv per year, - The exposure of pregnant workers must be limited and the effective dose is not allowed to exceed 1 mSv during pregnancy, - The workers must be informed of the risk due to cosmic radiation.	Assessment with computer code: all companies use CARI-6	Ai crew's annual dose should not exceed 6 mSv
France	Labour Code (article R.4451-140 to R.4451-144) Order of 8 December 2003	Evaluate if the dose can be higher than 1 mSv/y. If so, implement technical and administrative means to reduce the dose. If not possible to reduce below 1 mSv, occupational RP provisions for practices apply (assessment of exposure, medical surveillance, information, particular provision for pregnant women, etc.)	Assessment with SIEVERT (www.sievert-system.org)	/
Germany	Radiation Protection Ordinance § 103	- Manage the dose by appropriate crew allocation and flight planning - Inform the workers on risk due to cosmic radiation - Official dose monitoring if dose > 1 mSv/y - If pregnancy is announced female air crew members are allocated for ground service.	Aircrews likely to receive more than 1 mSv/y (depending on annual block time hours and altitude) are subject to individual monitoring by route dose calculation. Approved codes: EPCARD, PCAIRE or FREE	Specific requirements of medical check up if > 6 mSv/y (cat. A Worker)

Country	Regulation	Main requirements	Assessment of exposure	Dose criteria
Greece	Radiation Protection Regulation - § 1.2.5	- Inform the workers on risk due to cosmic radiation - Assess exposure of the crew and communicate information to GAEC if the dose is > 1 mSv, - Plan the route of the aircrew to reduce exposure of the most exposed persons	Assessment with computer code	Limit exposure above 6 mSv/y
Ireland	Ionising Radiation Order, SI No. 125 of 2000 Guidance note for air operators - 2008	If exposure can be higher than 1 mSv in a year: - Assess exposure of the crew - Take into account the assessed exposure when organizing flight schedules - Inform the workers on risk due to cosmic radiation - Limit the exposure of pregnant workers. - Take additional protective measures if the dose can be higher than 6 mSv/y (cat. A workers)	Assessment with CARI-6 or EPCARD software	Dose limit: 6 mSv/y (cat. B workers)
Italy	Legislative Decrees No. 230 and 241/2000 Chapter III bis - Article 10 octies	If regular flights over 8000 m (i.e. annual dose can be higher than 1 mSv): - Assess exposure of the crew - Rotate crew members to avoid big differences between exposures - Inform the workers on risk due to cosmic radiation, especially information in case of solar storm	Assessment with CARI-6 software	Action level: 1 mSv (aircrew flying regularly over 8000 m are category B workers)

Country	Regulation	Main requirements	Assessment of exposure	Dose criteria
Lithuania	Law on Radiation Protection Hygiene Standard HN 73:2001 Hygiene Standard HN 85:2003	If exposure can be higher than 1 mSv in a year: - Assess exposure of the members of air crew - Take into account the assessed exposure when organizing flight schedules - Inform the members of air crew on risk due to cosmic radiation - Limit the exposure of pregnant members of aircrew - Apply radiation protection measures as set for A category workers if effective dose exceeds 6 mSv/y	Assessment with CARI-6 software Direct measurements on flight were made in 2000, 2005 and 2007 (together with assessment using CARI-6)	Dose assessment for air crew members flying above 8000 m (individual dose can exceed 1 mSv/y) Specific requirements if individual dose of air crew > 6 mSv/y Public dose limit of 1 mSv for the unborn child of aircrew member
Slovenia	RP and Nuclear Safety Act § 45 and 46	- Assess exposure of the crew - Take into account the assessed exposure when organizing flight schedules - Inform the workers on risk due to cosmic radiation - Limit the exposure of pregnant workers.	No measurement Assessment with CARI-6 software using collected data for each flight	Dose limit: 6 mSv/y (cat. B workers) Dose constraint: 2 mSv/y (in 2009, 3 mSv/y)
Sweden	*Before July 2008* - international recommendations JAR-OPS 1 *Since Jult 2008* - Directive EEC 3922/91 and subpart D, OPS 1.390	In practice requirements of JAR-OPS 1 still used	Assessment with CARI-6 software	If the evaluated dose may be more than 6 mSv, individual assessment is required

Country	Regulation	Main requirements	Assessment of exposure	Dose criteria
The Netherlands	Radiation Protection Decree of 16 July 2011 - Chapter VIII - Article 111	Aircrew flying at altitude higher than 8000 m must be classified as exposed workers (class B). If the exposure reaches 6 mSv in one year, exposure limited by adjusting the job assignments	Assessment with CARI-6 software	Dose limit: 6 mSv/y (cat. B workers)
UK	Air Navigation (Cosmic Radiation) Order 2000	If exposure can be higher than 1 mSv in a year: - Assess exposure of the crew - Take into account the assessed exposure when organizing flight schedules - Inform the workers on risk due to cosmic radiation Limit the exposure of pregnant workers.	/	/

National data

Country	Air operators	Number of aircrew exposed	Annual effective dose
Belgium	Data from 7 air operators	*2009 data* 2,912 (1,766 with more than 1 mSv)	*2009 data* Average: 1.27 mSv Maximum: 4.77 mSv
Czech Republic	6 air operators	2,158	Average: 1.09 mSv Maximum: 3.95 mSv
Denmark	/	3,824	*2009 data* Average: 1.8 mSv Maximum: 6.0 mSv
Finland	6 air operators	*2009 data* 3,655 (1,195 pilots 2,460 cabin crew)	*2009 data* Average: 2.39 mSv Maximum: 5.6 mSv
France	Data from 2 air operators: Air France and Air Caledonia	19,830	*2009 data* Average: 2.2 mSv Maximum: 5.5 mSv
Germany	48 licences (commercial and non commercial, military)	*2009 data* 36,596	*2009 data* Average: 2.3 ± 1.3 mSv Maximum: 7.0 mSv
Greece	Data from the 2 main air operators	*2011 data (not analysed yet)*	/
Ireland	7 licensed air operators	9,726 persons receiving more than 1 mSv	/
Italy	7 commercial air operators under RP	9,560 cabin crew 6980 flight deck crew	
Lithuania	Data from 3 commercial air operators	213	*2009 data* Average: 2 mSv Maximum: 4.57 mSv
Slovenia	/	322 (138 pilots and 184 cabin crew)	*2009 data* Average: 1.16 mSv Maximum: 1.74 mSv
Sweden	Data from SAS	1,431 individuals exceeding 1 mSv in 2008	*2008 data* Average: 2.55 mSv Maximum: 5.43 mSv
The Netherlands	/	8,300 cabin crew 2,800 flight deck crew	*2007 data* Average: 1.73 Maximum: 4.55 *2002 data:* Average: 1.34 Maximum: 3.39
UK	/	About 40,000	Overall estimated average annual dose: 2 mSv

Detailed answers

BELGIUM

Regulation

RP of aircrew is addressed in the articles 4 and 9 of the Royal Decree of July 20, 2001 setting forth the general regulation for the protection of the population, the workers and the environment against the danger of ionizing radiation.

The requirements of article 9 of the Royal Decree of July 20, 2001 are an almost literal transposition of the requirements of the European Basic Safety Standards Directive (96/29 EURATOM – art. 42), i.e.

"*If the dose level of 1 mSv/y is exceeded or likely to be exceeded, the undertaking must:*

- *assess the individual doses of the personnel resulting from exposure to cosmic radiation;*
- *take into account these dose assessments in the organisation of the working schedules with the aim to reduce the doses of highly exposed air crew members;*
- *inform the concerned workers of the health risks their work involves;*
- *limit the doses during pregnancy (application of Art. 10 - 96/29 Euratom).* "

Airlines have to report the results of their dose-assessment to the *Federal Agency for Nuclear Control* (FANC), the Belgian Radiation Protection Authority.

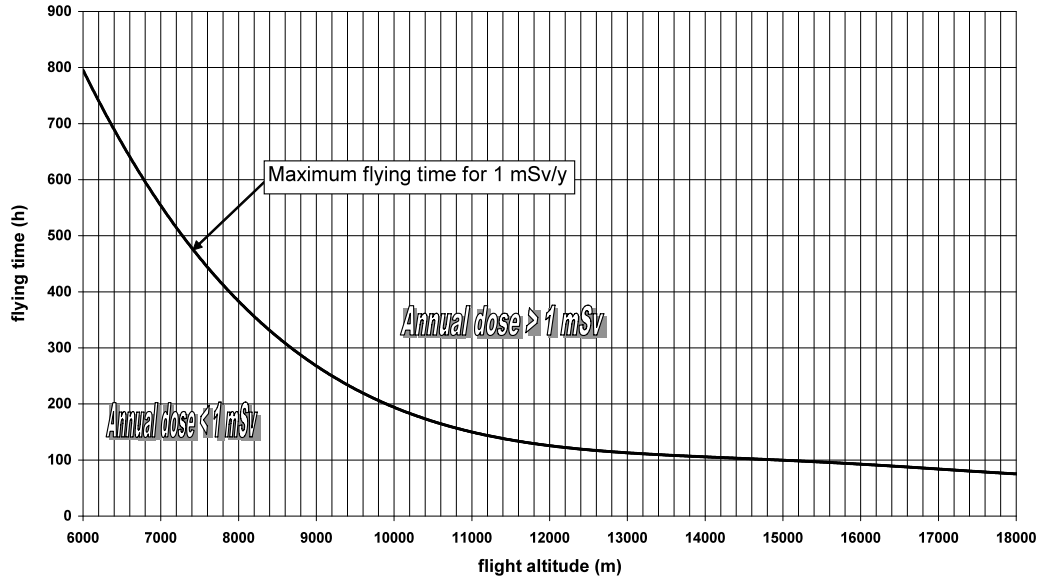
FANC has issued a technical guide, which describes the procedures for dose assessment. This guide is available from the website of FANC in French and in Dutch[1]. The guide contains a few straightforward criteria to readily assess whether aircrew members are unlikely to receive a dose higher than 1 mSv/y. These criteria are the following:

- Criteria 1: the company operates air planes with a maximum flight altitude of **6000 m** and the flying time doesn't exceed **770 hours,**
- Criteria 2: the company operates air planes with a maximum flight altitude of **14,000 m** and the flying time doesn't exceed **100 hours**,
- Criteria 3: based on the graph in **Figure 1**, it is possible to conclude that no aircrew member gets a dose higher than 1 mSv/y. This graph comes from the regulations developed by the German civil aviation authorities (Luftfahrt Bundesamt[2]).

[1] http://www.fanc.fgov.be/fr/page/rayon-cosmique/1191.aspx

[2] Luftfahrt Bundesamt, Rundschreiben, Meldungen entsprechend Strahlenschutz-verordnung (2005).

Figure 1: Delimitation of the zone where the annual dose may be higher than 1 mSv as a function of flying time and flight altitude



If none of these criteria applies, the company must assess the individual dose using a **computer code**. The codes used by Belgian airlines are the following: IASON-FREE, PCAIRE, CARI and GLOBALOG. The code must not be accredited by the authority.

The requirements described in article 9 of the Royal Decree (assessment of individual doses, information of workers, etc.) are applicable as soon as the individual dose may exceed **1 mSv/y**. There are no other specific dose criteria mentioned in the regulation itself[3] but the policy of FANC is to consider a crew member as "highly exposed" if the level of **6 mSv/y** is exceeded. 6 mSv/y is considered as an intervention level for further requirements (e.g. medical surveillance, reporting of monthly dose, adjustment of rostering) – following the recommendations of the European Commission document *"Radiation Protection 88"* (Section 4).

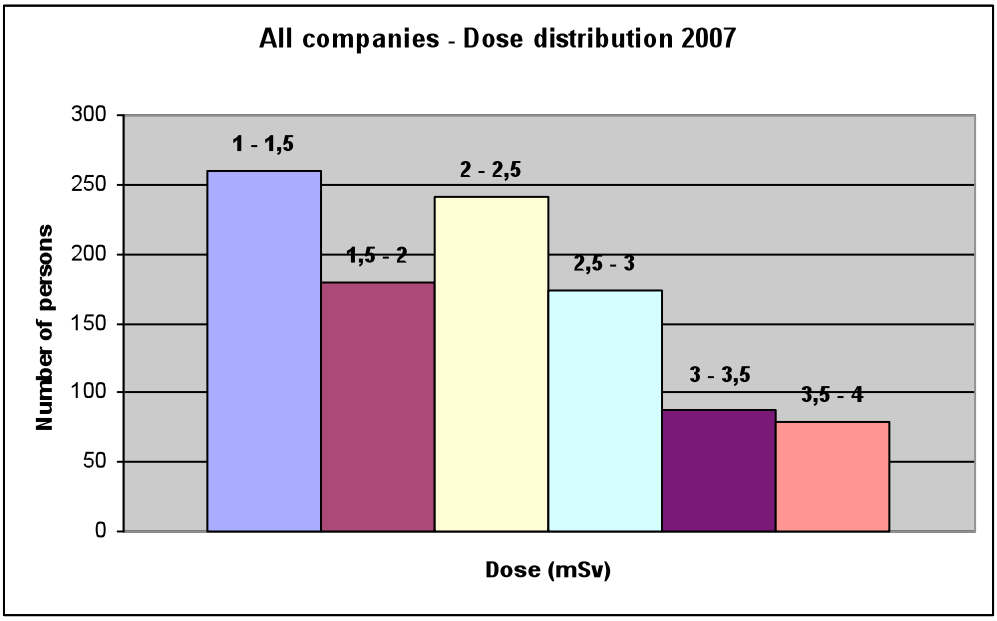
Data

There are **7** Belgian airlines for which the dose level of 1 mSv/y is exceeded. The individual doses have been collected by FANC since 2008. The following table and graph gives an overview of the data:

[3] For pregnant crew members, from the moment of the declaration of pregnancy, the conditions for the pregnant woman in the context of her employment shall be such that the dose to the unborn child will be as low as reasonably achievable and that the dose may not exceed 1 mSv **for all the duration of the pregnancy**. If this dose is already exceeded at the moment of the declaration of the pregnancy, the pregnant woman will be excluded from any work with a risk of exposure to ionising radiation.

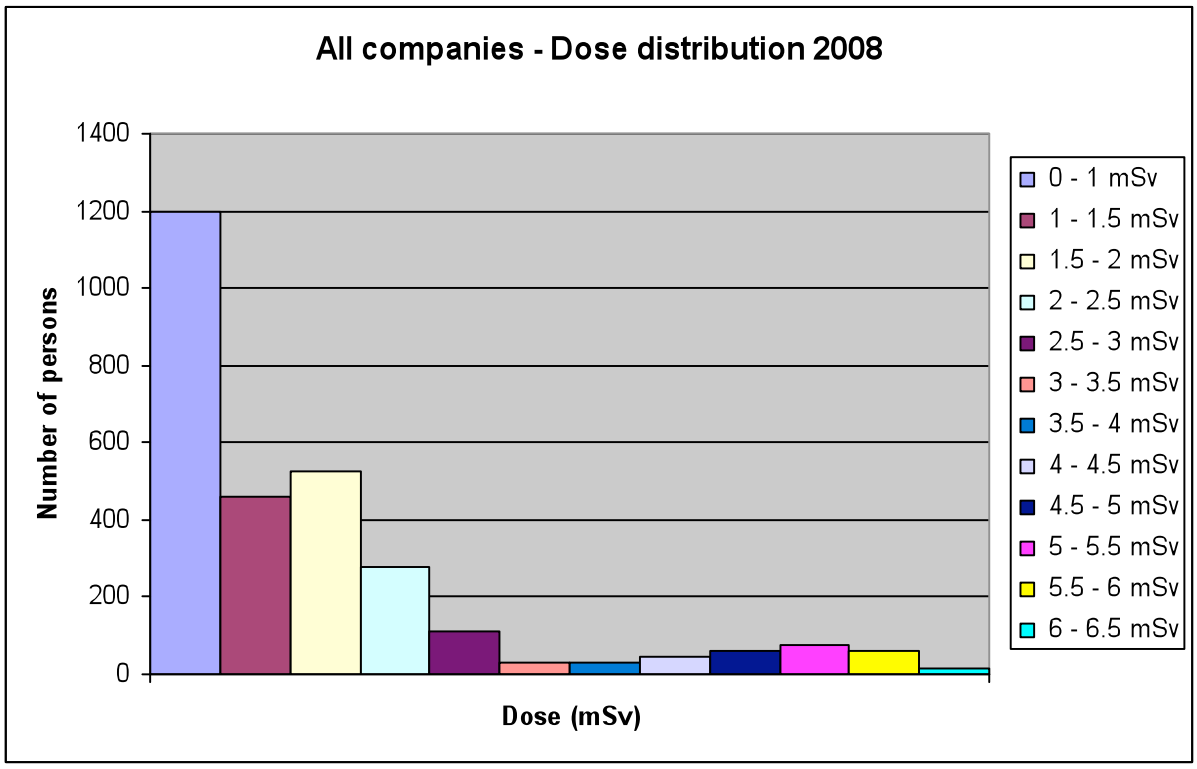
	2007	***2008***	***2009***
Number of individual doses received	**1019**	**2893**	**2912**
# < 1 mSv/y	**?**	**1197**	**1146**
1 – 1.5 mSv/y	260	460	555
1.5 – 2 mSv/y	179	525	611
2 – 2.5 mSv/y	241	279	208
2.5 – 3 mSv/y	173	110	192
3 – 3.5 mSv/y	87	32	116
3.5 – 4 mSv/y	79	31	79
4 – 4.5 mSv/y	0	43	4
4.5 – 5 mSv/y	0	61	1
5 – 5.5 mSv/y	0	78	0
5.5 – 6 mSv/y	0	62	0
6 – 6.5 mSv/y	0	15	0
1 – 6 mSv/y	**1019**	**1681**	**1766**
> 6 mSv/y	**0**	**15**	**0**
Average dose (mSv/y)	**-** [4]	**1.56**	**1.27**
Maximal dose (mSv/y)	**3.98**	**6.47**	**4.77**

Graph 1 - Dose distribution 2007

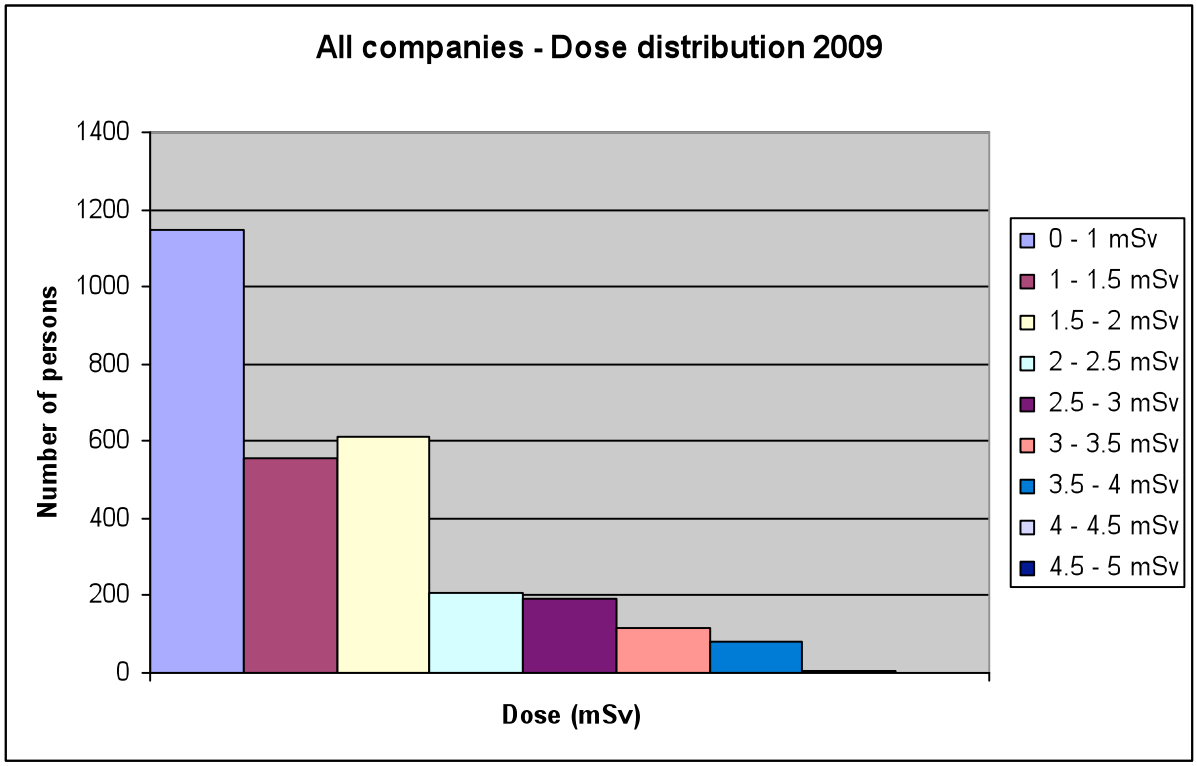


[4] As the number of aircrew members with a dose < 1 mSv/y is not known for 2007, the average was not calculated.

Graph 2 - Dose distribution 2008



Graph 3 - Dose distribution 2009



CZECH REPUBLIC

Regulation

Part Three of the *Regulation No. 307/2002 Coll. of 13 June 2002 on Radiation Protection*, issued by the State Office for Nuclear Safety, forms the basis for radiation protection to aircrew. The relevant parts of the legislation are reproduced in the following:

"PART THREE - WORK ACTIVITIES ASSOCIATED WITH INCREASED EXPOSURE TO NATURAL SOURCES

§ 87 - Workplaces with a Possibility of Significantly Increased Exposure to Natural Sources
Workplaces where an increased exposure to natural radiation sources may be expected are as follows:
a) Aircraft boards in flights at an altitude over 8 km; […]

§ 88 - Scope of Measurements and Keeping Records on Results
[…]
c) at aircrew members operating on airplane boards at an altitude over 8 km by determining an aircrew flight schedule, flight parameters and other parameters which are important for calculation of an effective dose in compliance with the approved methods and by calculation of an effective dose per calendar year; […]

(4) The data measured and the annual effective doses per calendar year for the persons performing work at the workplaces where the guidance levels under Section 90 paragraph 2 a) and b) have been exceeded, as well as for the aircrew members operating on airplane boards at an altitude over 8 km, shall befiled during the whole period of their working life and afterwards until the persons have or would have attained the age of 75 years, but in any case not less than 30 years from the termination of the work involving exposure.

(5) The Office's state system of records of exposure of individuals shall be notified once a year in summary directly or through a person who performs the approved dosimetric service of the names, surnames, birth registration numbers, if assigned, and the data of effective doses of all the persons performing work activities in the environment with a significantly increased exposure to natural radiation sources under Section 91.

§ 90 - Guidance Levels
(1) For the members of aircrews who operate on airplane boards at an altitude over 8 km, the guidance level for the reduction of exposure to cosmic rays shall be an effective dose of 1 mSv per calendar year. If this guidance level might be exceeded, the members of aircrews shall be informed on the magnitude of their exposure and the health risk, and radiation protection optimisation shall be performed. For this purpose, the exposure of individual aircrew members shall be evaluated, and based on this evaluation their flight schedules shall be prepared and/or modified.
[…]

(3) Working conditions of pregnant women shall be modified in accordance to Section 23

paragraph 2 for work activities with an increased exposure to natural sources.

§ 91 - Significantly Increased Exposure to Natural Sources
(1) For persons performing work activities at the workplace laid down under Section 87 b), c), d) and e) and if after applying countermeasures corresponding to the optimisation of radiation protection it shall not be possible to reduce effective doses per calendar year for such persons below 6 mSv, and as well as for aircrews members if it is not possible to reduce an effective dose below 1 mSv, radiation protection shall be ensured in the scope and the manner that is applied for controlled areas of the workplaces where radiation activities are performed. […]"

DENMARK

Regulation

Extracts from: Evaluation of the implementation of radiation protection measures for aircrew, *Radiation Protection No. 159, European Commission, 2009*

Aviation in Denmark is governed by the *Air Navigation Act Order, Consolidated Act no. 1484 of 19 December 2005*, issued by the Ministry of Transport and Energy. However, it does not contain provisions on radiation protection for aircrew.

The Civil Aviation Administration (Statens Luftfartsvæsen, AIS / Luftfartsinformationstjenesten, Kopenhagen) has issued guidelines on the Control of the Exposure to Cosmic Radiation of Air Crew in the Nordic Countries (document AIC B-04 / 03), in which recourse is made to the JAR-OPS. This document is reproduced in the following:
"*Dose rates from cosmic radiation vary strongly with altitude and also with latitude and with the phase of the solar cycle. The exposure of aircrew to cosmic radiation can be significantly increased dependent on rostering. The Nordic Radiation Protection and Civil Aviation Authorities have agreed on the following interpretation of requirements for the control of the exposure to cosmic radiation of aircrew in the Nordic countries. The interpretation take due account of the requirements in JAR-OPS 1.390 and 1.680 regarding cosmic radiation (ref. 1), the revised European Basic Safety Standards Directive (ref. 2) and the guidance made by the European Commission in transposing the Directive into national legislation (ref. 3).*

1. *Operators of aircraft in commercial air transport registered in a Nordic country or operating on a Nordic AOC (Air Operator Certificate) shall take the exposure of air crew (both flight deck and cabin crew) to cosmic radiation into account in accordance with these recommendations if the annual effective dose to a crew member can exceed 1 mSv.*
2. *The operator (employer) shall inform the aircrew of the risks of occupational exposure to cosmic radiation. Female aircrew shall know of the need for early declaration of pregnancy in view of the risks of exposure for the child to be born.*
3. *Effective doses to air crew can be estimated by the operator by using route doses calculated with a suitable computer programme4 taking generic or specific flying circumstances into account. Other means of estimating the exposure to air crew shall be approved by the National Radiation Protection Authority in cooperation with National Civil Aviation Authorities to ensure adherence to JAR-OPS 1. Operators, who before each traffic season can demonstrate annual average crew radiation exposure well below*

6 mSv based on the average flying pattern and expected average number of flight duty hours, can use actual duty hours as a scaling factor for estimating individual effective doses. The average crew radiation exposure estimate must take into account the varying flying pattern of different groups of crew members, if applicable.

4. *The operator shall after each calendar year estimate the effective dose to each individual crew member in accordance with paragraph 3 and inform the crew member of his/her effective dose.*
5. *Once a year before 01 March the operator shall forward the following information regarding the previous calendar year to the national radiation protection authorities: Statens Institut for Strålehygiejne; Knapholm 7; DK-2730 Herlev; Denmark*
   (a) *A summary of the estimated yearly effective doses to the air crew (Number of crew members in each 1 mSv interval (< 1 mSv, 1-2 mSv, 2-3 mSv, 3-4 mSv, etc.)).*
   (b) *A list of crew members with an estimated yearly effective dose equal to or above 6 mSv (Full name, national identification number and estimated dose in accordance with national legislation on personal registries).*
6. *When organising working schedules the operator shall take into account the estimated effective doses with a view to reduce individual yearly doses at for those individuals whose yearly effective dose is estimated to be at or above 6 mSv.*
7. *When a pregnant crew member informs the operator of her condition, the operator shall ensure that the working schedule for female crew members, once they have notified the operator that they are pregnant, keep the equivalent dose of the foetus as low as can reasonably be achieved and in any case ensure that the dose does not exceed 1mSv for the remainder of the pregnancy."*

Data

The present number of aircrew exposed is 3824. 1140 of the aircrew had doses beneath 1 mSv/a:

- Average annual effective dose: 1.8 mSv (2009),
- Maximum annual effective dose: 6.0 mSv (2009)

FINLAND

Regulations

- Radiation Act 1991/592 - Chapter 12,
- Radiation Decree 1991/1512 - Chapter 7,
- Guide ST 12.4 - Radiation safety in aviation.

The main requirements of the regulation are the following: if exposure can be higher than 1 mSv in a year:

- Exposure of the aircrew must be monitored and the assessed doses announced to the Dose Register,
- Work shifts and flight routes must be planned to ensure that the worker's annual effective dose does not exceed 6 mSv per year,
- The exposure of pregnant workers must be limited and the effective dose is not allowed to exceed 1 mSv during pregnancy,
- The workers must be informed of the risk due to cosmic radiation.

According to Guide ST 12.4 the assessment must be done with computer code: EPCARD, CARI-6, FREE. In Finland, all airline companies currently use CARI-6.

Data

For the year 2009:
- Number of airline companies in Finland: 6,
- Average dose of air crew: 2.39 mSv,
- Maximun dose: 5.6 mSv

The following table present for 2005 to 2009 the number of air crew members subject to individual monitoring of radiation exposure and the corresponding total collective dose

Year	Number of workers		Total collective dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2005	739	1861	1.31	3.80
2006	1072	2412	1.73	4.35
2007	1125	2583	2.30	5.61
2008	1206	2562	2.45	5.93
2009	1195	2460	2.68	6.07

FRANCE

Regulations

Requirements for radiation protection of aircrew are in the Labour Code, articles R-4451-140 to R-4451-144. Modalities for application are set in a ministerial order of 8 December 2003. They are based on the requirements of the European Directive Euratom 96/29.

The employer must assess the doses that the aircrew may receive during the flights due to cosmic radiations. If individual doses may be more than 1 mSv in a year, the employer takes the administrative and technical actions to reduce the exposure.

If theses preventive actions do not allow reducing individual doses below 1 mSv per year, requirements in terms of occupational radiological protection for practices apply. This includes designation of a competent person in radiation protection (qualified expert) by the employer, individual dose assessment, information and medical surveillance for those aircrew likely to receive dose more than 1 mSv per year, dose limitation, particular provisions for pregnant women. This excludes definition of regulated areas, operational dosimetry and workplace area controls.

The individual actual effective dose received by aircrew likely to receive dose more than 1 mSv per year is assessed for each flight using a calculation model and based on the flight data (date, duration, starting point, destination, way, solar activity). Results of the individual dose assessment are sent by the designated competent person in radiation protection to the Institute of radiation protection and nuclear

safety (IRSN) and saved individually by IRSN in the national occupational dose register.

Data

Reference: "La radioprotection des travailleurs : exposition professionnelle aux rayonnements ionisant en France - bilan 2009", IRSN

In 2009, 16 French air operators (representing about 23,300 aircrew) have used the SIEVERT model to evaluate the doses received by aircrew. However, only two air operators (Air France and Air Caledonia International) sent the results to IRSN. The table below summarizes the information received from these two air operators.

Aircrew	Distribution of individual effective dose (mSv)						Mean dose	Maximum dose
	< 1	1-2	2-3	3-4	4-5	5-6		
19,830	2,985 (15.1%)	5,865 (29.6%)	5,864 (29.6%)	4,398 (22.2%)	711 (3.6%)	7	2.2	5.5

GERMANY

Regulation

Legal situation

In Germany, the protection of aircraft crew against the exposure from cosmic radiation is regulated in § 103 of the German Radiation Protection Ordinance. The official dose monitoring for aircraft crew was established in August 2003. Aircraft personnel are subject to occupational radiation protection surveillance if they are employed by an airline company in accordance with the German employment law. The duty to calculate the flight doses lies in the responsibility of the licensee, i.e. airline company that operates the flight. The airline operator has also to take measures to keep the doses of the personnel low by appropriate crew allocation and flight planning. Furthermore, the airline operator has to instruct the crew members regularly about the nature of cosmic radiation and its risk of adverse health effects. Through this legal requirements of dose monitoring and dose reduction, aircrew members receive a legally based radiation protection which is equivalent to all other occupationally radiation exposed workers.

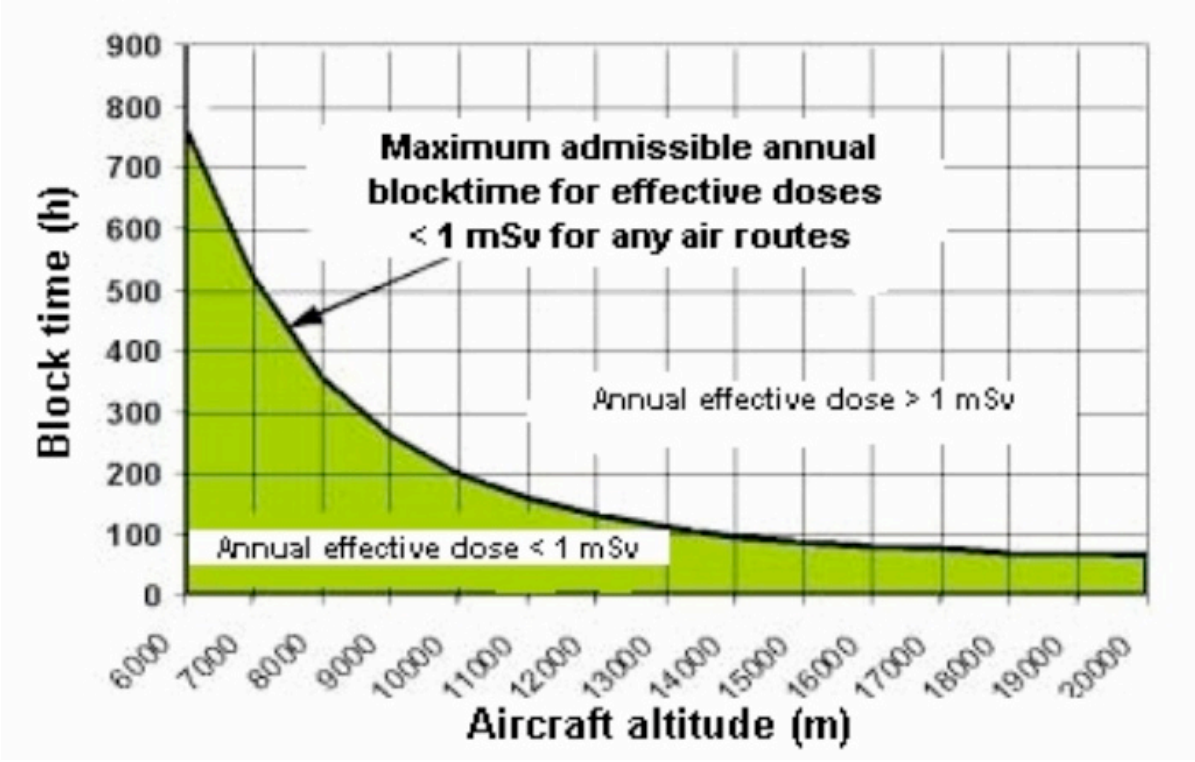
Two Federal Offices are involved in the surveillance: the Federal Office for Civil Aviation ("Luftfahrt-Bundesamt, LBA") is the responsible authority for all regulatory aspects and is in direct con- tact with the airline companies. The Radiation Protection Register (Strahlenschutzregister, SSR) in the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS) is the German central dose register for occupational radiation exposure and thus responsible for the individual assembling of all dose recordings from any kind of occupational radiation exposure, the central and long term record keeping, the surveillance of the keeping of dose limits and the scientific analysis of the radiation exposure under the aspect of optimisation.

Who is monitored?

Aircraft crew members are subject to official dose monitoring if it cannot be excludedthat they can receive an effective dose of more than 1 mSv per calendar year

from cosmic radiation during flight operation. The 1 mSv-threshold can be described as a limiting function of the number of flight hours (block time) and cruising altitude of aircraft (see Fig. 1). This limiting curve can be used to select those aircraft crew members who have to be monitored, because their individual combination of cruising altitude and block time exceeds the 1-mSv-limit. Crew members of turbo-prop aircrafts, helicopters, and some part-time workers can normally be excluded from dose monitoring.

***Figure 1**: Limiting curve for the keeping of 1 mSv in dependence of the maximum permissible flight hours (block time) and the cruising altitude of the aircraft (Source: Physikalisch-Technische Bundesanstalt, Germany)*



Dose calculation and monitoring

Technically, it is possible to measure the dose rate during flight, e.g. with tissue-equivalent proportional counters (TEPC) installed in the aircraft. But as the physical conditions of cosmic radiation are well known, the route doses can be sufficiently exact calculated by computer programs.

In Germany, dose calculation programs used for official monitoring of flight doses require the approval by the LBA. In order to get this approval, the program has to undergo a certification process by the German National Metrology Institute ("Physikalisch-Technische Bundesanstalt, PTB"). During that procedure it is to prove that a calculation program fulfils quality standards for dose calculation (e.g. underlying physical approach, calculation code) and electronic data processing (e.g. requirements for data safety, security, and integrity). Three programs are currently certified by the LBA for the use of official dose calculation for aircraft crew (EPCARD, PCAIRE, FREE). The mostly used program in Germany is EPCARD, which was developed by the HelmholzZentrum München (former GSF) on behalf of

the European Commission.

An airline company or a service provider who act on behalf of the licensee calculates the individual route dose that is expected on a flight. The input parameters for dose calculation are taken from the flight planning system of the airline. Input parameters are: dates of flight, airport of origin, airport of destination, ascend time, time on route, cruising altitude, and descend time. The calculated route doses are assigned to each aircraft crew member that is on that flight (for both active crew member and crew who are on a transfer flight ("dead head" flights)). Doses are re-calculated if the conducted flight differs substantially from the originally planned flight.

The dose data are regularly transmitted from the airline company to the LBA. The LBA uses the route doses for its specific regulatory tasks, accumulates the doses to individual monthly doses and sends these accumulated monthly doses with additional individual attributes (name, ID-number, monitoring period, effective dose, crew status, airline, etc.) to the SSR.

Aircraft crew members are normally assigned to radiation workers of category B. In those cases where an annual dose of 6 mSv is possible, they are assigned to category A which implies an annual medical check-up by an authorised physician. When an aircraft crew member announces an existing pregnancy then the operating airline is obliged to prevent her from flying and allocate her to ground service.

Research for quality assurance
On behalf of the BfS the PTB is presently executing a research project for the quality assurance of dose calculation programs. In this project route doses on typical long haul routes are measured and compared with dose calculations. The time series of these measurements shall cover half of a solar cycle (from the last solar minimum to the next maximum). They shall also take into account the impact on dose calculation that come from of the drift of the geomagnetic poles and – as the case may be – from solar particle events (solar flares).

Data

Dose statistics for aircraft crew in Germany 2009
No of licensees (commercial and non-commercial airlines, military): 48
No of workers (cockpit, cabin, others): 36,596
Collective dose: 85.9 Pers.-Sv
Mean annual dose ± sdev: 2.3 ± 1.3 mSv
Median: 2.4 mSv
Maximum: 7.0 mSv

The BfS is presently preparing a detailed report on aircraft crew exposure from 2004 – 2009 in Germany. The report is expected to be published in early 2011.

GREECE

Regulation

Extracts from: Evaluation of the implementation of radiation protection measures for aircrew, *Radiation Protection No. 159, European Commission, 2009*

Radiation protection of aircrew members in Greece is governed by the Radiation Protection Regulation as follows:

"***1.2.5. Significant increase in exposure due to natural radiation sources***

1.2.5.1. The Greek Atomic Energy Commission shall be the competent authority for identifying, on the basis surveys or any appropriate method, the workplaces in which the presence of natural radiation sources (terrestrial or cosmic) lead to a significant increase in the exposure of workers, which cannot be disregarded from the radiation protection point of view.

1.2.5.8. Airline companies must inform flight personnel, when they take up their duties for the first time, about exposure to cosmic radiation and the associated health hazards. Airline companies must be equipped with appropriate computer programmes, approved by the GAEC, for the measuring the doses received by flight personnel. The results of the dose measurements of flight personnel whose dose exceeds 1 mSv per year shall be communicated to the GAEC. Airline companies shall plan the routes of their flight personnel so as to reduce exposure of the most exposed personnel; exposure may not exceed 6 mSv per person in a year. Pregnant workers are entitled to require the airline company to relieve them of flight personnel duties."

In practice the air crew doses are calculated by the CARI – 6 computer code. The dose calculations are performed by the airline companies. The results are sent to GAEC where they are kept in the National Dose Registry. The airline companies have started sending the results since January 2011.

IRELAND

Regulation

Extracts from: Guidance note to assist operators to comply with regulation governing occupational exposure of aircrew to cosmic radiation, *RPII, 2008*

What air crew exposures are likely to be of concern?
Current scientific evidence suggests that air crew who fly exclusively below altitudes of 8,000 m (~26,200 feet) are unlikely to receive cosmic radiation doses in excess of 1 mSv in any 12 month period. Therefore, an 8,000 m (~26,200 feet) altitude limit can be used to identify those staff liable to receive in excess of 1 mSv over 12 months. Consequently, only those air crew who fly at altitudes above 8,000 m come within the scope of the Regulations.

Furthermore, aircraft operating above 15,200 m (~50,000 feet) are required by the JAR-OPS Regulations2 to be equipped with cosmic radiation detection and

measurement equipment. Above this altitude increased cosmic radiation due to high levels of solar activity caused by solar flares must be taken into account when determining air crew doses.

As an operator what do I have to do?
Each operator is required to carry out an evaluation of the exposure of its air crew from cosmic radiation. This evaluation must be carried out once. However, if at some future time there is a change to work practices, for example if new routes are added, then the evaluation will need to be repeated. The evaluation should be forwarded to the RPII within three months of completion.

The purpose of such an evaluation is to determine if the work carried out by the operator falls within the scope of the Regulations. In particular the purpose of the evaluation is to:
- identify air crew liable to receive in excess of 1 mSv in any period of 12 months (Category B workers); and
- identify air crew liable to exceed 6 mSv in any period of 12 months (Category A workers);

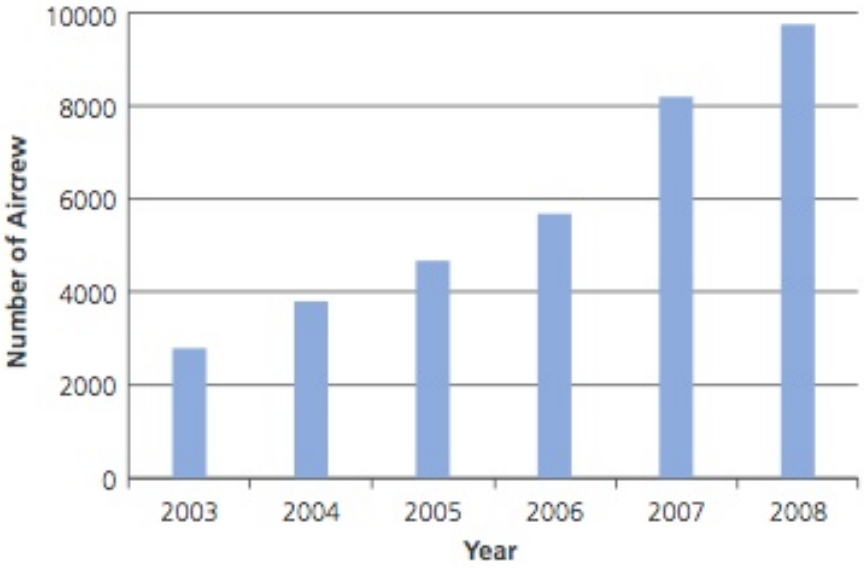
Where the evaluation shows that air crew are liable to receive doses of greater than 1 (mSv) in any 12 month period, the operator must:
- inform the air crew on the risks involved;
- assess the exposure to individual air crew;
- maintain records of such assessments;
- make available such records to the air crew concerned;
- provide to the RPII summaries of the dose records as given in Schedule 1 of these notes;
- take special provisions relating to female air crew on declaration of pregnancy; and
- take additional protective measures in relation to air crew liable to receive cosmic radiation doses in excess of 6 mSv in any 12 month period.

How are the doses to air crew calculated?
For aircraft flying at altitudes above 8,000 m (~26,200 feet) and below 15,000 m (~50,000 feet) (i.e. the air crew are likely to receive an annual dose in excess of 1 mSv, but the aircraft is not required to be equipped with cosmic radiation detection equipment) it is recommended that assessment of each individual air crew dose be determined by combining route dose with crew roster data. Route dose estimates can be calculated using computer programs specifically designed for that purpose. The computer programs EPCARD (European Package for the Calculation of Aviation Route Doses) and CARI3-6 have been approved by the European Commission4. The RPII recognises a dose assessment carried out using either of these two programs.
Data

Under S.I. No. 125 of 2000 the holder of an air operator's certificate is required to evaluate doses received by aircrew to determine if measures to control exposure to cosmic radiation are warranted. This requirement applies to those air operators whose aircrew is potentially liable to receive an annual dose greater than 1

millisievert (mSv), which effectively applies only to those airlines flying above 8000 metres. Doses are estimated by the airlines using internationally recognised software models. For 2008, the information received from seven licensed air operators showed that 9726 individuals were estimated to receive annual radiation doses above 1 mSv. Of these, 3695 received between 1 and 2 mSv, while 5779 received doses between 2 and 4 mSv and 252 received doses over 4 mSv. No doses over 6 mSv were reported. Since monitoring of aircrew began in 2003 there has been a consistent yearly increase in the number of aircrew receiving doses in excess of 1 mSv (figure below). This can be attributed to an increase in the number of aircrew required for the operation of new and existing routes as the demand for air travel increases.

Figure 1. *Number of air crew receiving a radiation dose greater than 1 mSv*



ITALY

Regulation

Extracts from: Evaluation of the implementation of radiation protection measures for aircrew, *Radiation Protection No. 159, European Commission, 2009*

Occupational radiation protection in Italy is governed by *Legislative Decree No. 230 of 1995* and *241 of 2000*. Article 10 octies (Chapter III bis) governs radiation protection for air crew members. The article regulates the duties of the employer to modify rosters to reduce exposure, to inform employees about the health risks of ionising radiation and to communicate the type of activity in relation to the definitions in the article. Other duties, which are not specific to aviation but are due to all types of exposed occupations, are defined in chapter VIII.

Data

Extracts from: Evaluation of the implementation of radiation protection measures for aircrew, *Radiation Protection No. 159, European Commission, 2009*

A National Dose Register is not available in Italy.

According to the Italian Civil Aviation Authority (*Ente Nazionale per l'Aviazione Civile*) there are 48 registered commercial airlines, 44 non-commercial airlines for aerial work and 137 non-commercial from registered facilities in Italy. Seven of the commercial airlines are under radiation protection but none of the non-commercial. This is due to the criteria for the exclusion (operators of helicopters; aircrafts flying beneath 8000 m). Thus, there are 9560 cabin crew and 6980 flight deck crew members in Italy under radiation protection. In none of the aircrafts registered in Italy is dose measurement equipment included.

LITHUANIA

Regulation

Law on Radiation Protection (adopted on 1999 last amended 2010).

Hygiene Standard HN 73:2001 "Basic Standard of Radiation Protection" adopted by the Order No. 663 on 21 December 2001 by the Minister of Health Care.

Hygiene Standard HN 85:2003 "Natural Exposure. Standards of Radiation Protection" adopted by the Order No. V-749 on 22 December 2003 by the Minister of Health Care.

The Law on Radiation Protection rules the monitoring of occupationally exposed workers in general. At present Order of Director of Radiation Protection Centre is under development in order to provide more detailed information and regulation, to ensure evaluation of aircrew exposure by the operator, reporting on exposure doses of aircrew members to the Regulatory authority.
The main requirements laid down in Hygiene standards are the following:

Hygiene Standard HN 73:2001 "Basic Standard of Radiation Protection" adopted by the Order No. 663 on 21 December 2001 by the Minister of Health Care:
74. Radiation protection of aircrews is ensured according to the order defined by legislation, however:
74.1. If due to cosmic radiation the members of aircrews can receive annual effective doses higher than 1 mSv, the following steps shall be taken:
74.1.1. Doses of members of aircrews shall be assessed;
74.1.2. The dose assessments shall be taken into account when organizing working schedules of members of aircrews in order to reduce the doses of highly exposed members of aircrews;
74.1.3. Requirements of para.44 shall be applied to female aircrews members;
74.1.4. Members of aircrews shall be informed about health risks due to their work.

44. Protection of pregnant and breastfeeding female workers:
44.1. Female worker shall, on becoming aware that she is pregnant, notify the licensee in order that her working conditions may be modified. The condition for the pregnant female worker in the context of her employment shall therefore be such that the foetus is protected according to the para.B.4 of Annex B and the equivalent dose to the foetus will be as low as reasonably achievable and this dose will not exceed 1 mSv during at least the remainder of the pregnancy;
44.2. Notification on pregnancy shall not be considered to be a reason to exclude a pregnant female worker and apprentice (student) from work;

Para.B.4 of Annex B
B.4. Dose limits for members of the public shall be:
B.4.1. Annual effective dose – 1 mSv;
B.4.2. In special circumstances, annual effective dose - 5 mSv, provided that the average dose over five consecutive years does not exceed 1mSv per year;

Hygiene Standard HN 85:2003 "Natural Exposure. Standards of Radiation Protection" adopted by the Order No. V-749 on 22 December 2003 by the Minister of Health Care.
10. Measures shall be taken for radiation protection of members of aircrews to exposure to cosmic radiation. This hygiene norm regulates the exposure to cosmic radiation to members of aircrews.

VIII. Radiation protection of members of aircrew
31. The requirements of this chapter are applicable to aircrews of aircraft flying on altitudes higher than 8000 m. Annual effective doses of aircrews of aircraft flying on lower altitudes will not exceed 1 mSv.
32. Employers of aircrews shall assess the possible additional maximum effective dose, which will be received by a member of aircrew per year as a result of exposure to cosmic radiation. If this dose does not exceed 1 mSv no radiation protection measures are to be taken.
33. If the possible additional maximum effective dose which are received by a member of aircrew per year exceeds 1 mSv but does not exceed 6 mSv the following radiation protection measures shall be taken:
33.1. Employers shall establish the flying schedules in such a way that additional annual effective dose does not exceed 6 mSv.
33.2. Pregnant members of aircrews shall inform their employer about pregnancy. The employer shall take steps that radiation protection of unborn child complies with the radiation protection requirements set for public and the dose to unborn child does not exceed 1 mSv during the remaining pregnancy.
33.3. Employers shall inform the members of aircrews about possible impact of additional exposure on their health.
*34. If the additional annual effective dose exceeds 6 mSv all the radiation protection measures set by [*Hygiene Standard HN 73:2001 "Basic Standard of Radiation Protection"*] for A category workers are to be taken.*

To assess exposure, the Radiation Protection Centre cooperates with aircraft operators and calculates aircrew exposure doses using Cari-6 software. Direct measurements on flights together with calculations using Cari6 were done in 2000, 2005 and 2007 for different operators.
Action levels of 1 mSv and 6 mSv for aircraft members and public dose limit of 1 mSv for the unborn child are mentioned in Hygiene standard 85:2003.

Data

In Lithuania were 3 commercial airlines operators flying above 8000 m in 2010. Number of exposed aircrew members is 213 (80 flight deck crew and 133 cabin crew members, altogether 96 men and 117 women).

Exposure evaluation of 3 commercial airlines air crew exposure data for whole year (12 months) was carried out. For 2 of them for period 2009 and one of them for period from July 2009 to June 2010 (period of 12 months) - this airline worked only part of 2009 year -, the average dose for air crew members was about 2.0 mSv and the highest dose was 4.57 mSv.

SLOVENIA

Regulation

Paragraphs 45 and 46 of the Slovenian Radiation Protection and Nuclear Safety Act (Off.Gazette No. 102/2004-consolidated text) are in accordance with the Paragraphs 40 and 42 of the 1996/29/Euratom Directive.

The main requirements are the following:
- Assess the exposure of the crew,
- Take into account the assessed exposure when organizing flight schedules,
- Inform the workers on risk due to cosmic radiation,
- Limit the exposure of pregnant workers.

Means and tools to assess exposure are based on calculations:
- Collect data (destinations, dates, altitudes/durations including climbs/descends) for individual flights,
- Use computer programme CARI-6 for effective dose calculation;
- Sum the doses for the most exposed individual;
- Estimate doses for other individuals;
- Find extremes for individual destinations;
- Estimate theoretical maximal dose for the most exposed individual.

Because Slovenian flying company performs only regional flights, measurements are not requested.

The individual dose limit for aircrew is 6 mSv/y (category B). Operative dose constraint is now reduced from 3 mSv/y to 2 mSv/y, because in 2009 nobody didn't receive higher dose than 1.75 mSv. Airline operator properly rotates its workers.

Data

- Number of aircrew for 2009: 322 persons: 138 aviators/pilots (Airbus+CRJ) and 184 flight attendants/cabin crew,
- Maximum individual exposure in 2009: 1.74 mSv for a pilot in CRJ (896 flight-block hours),
- Average individual exposure: estimated to be 2/3 of maximum, i.e. 1.16 mSv in 2009,
- Maximum theoretical estimated dose in 2009: 3.44 mSv for flights Ljubljana - Moscow - Ljubljana in 900 hours.

SWEDEN

Regulation

Before July 16 2008, the Swedish air traffic followed the international recommendations of JAR-OPS 1. After July 16 2008 JAR-OPS 1 was replaced by the directive EEC 3922/91, and subpart D, OPS 1.390. Although in reality the air companies are still following JAR-OPS 1 with its more detailed formulation of requirements.

The main requirements according to JAR-OPS 1 are the following:
- To assess exposure, the latest version of the software CARI6 should be used,
- No specific dose criteria is used, except for 6 mSv as a potential exposure limit for which individual assessment is required.

Data

SAS is the only company reporting to the authority in Sweden. According to the SAS annual report:
- Average individual effective dose in 2008: 2.55 mSv,
- Maximum individual effective dose 5.43 mSv,
- 1431 individuals exceeding 1 mSv.

Since 2002, the trend has been clear: annual doses (both maximum and average) of both pilots and cabin crew are increasing.

THE NETHERLANDS

Regulation

Radiation Protection Decree of 16 July 2001 - Chapter VIII - Article 111
The main requirements are the following:
- Aircraft crew flying at altitudes higher than 8000 meter shall be classified as exposed workers,
- Dose limits are the same as for normal exposed workers, i.e. 6 mSv for class B exposed workers,
- If exposure for an individual worker reaches 6 mSv on annual base, the exposure should be limited by adjusting the job assignments (e.g. to fly on other routes with lower exposure),
- There are no cases of aircraft crew classified as class A exposed worker,
- For pregnant workers normal limitations apply: maximum of 1 mSv for the foetus from the moment of declaration of pregnancy until moment of birth,
- Classified exposed workers are subject to monitoring of the dose,
- Monitoring of air crew is done by calculation of the dose based on flight data (date and time of the flight, detailed flight plan if available, otherwise calculated trajectory from airport departure to destination) and the working schedule (which worker was on which flight) using an approved model (in NL: CARI6),
- Results of the monitoring are registered in the National Dose Registry (NDRIS).

Data

Number of registered aircraft crew:

Cabin crew members	
Male	1,600
Female	6,700

Flight deck crew members	
Male	2,700
Female	100

Evolution of doses for aircraft crew between 2002 and 2007

- Average doses increased, ca. 7% per year, mainly due to influence of the solar cycle,
- Maximum doses increased slightly ca. 8 à 9 % per year. However the maximum values show statistical fluctuations, because the maximum value is based on only one number.
- The 99-percentile (dose value exceeded by 1% of the employers) is less sensitive for statistical fluctuations than the maximum value of the dose. This value increased ca. 6% per year, mainly due to influence of the solar cycle.

Year	Average dose (mSv)	99-percentile (mSv)	Maximum dose (mSv)
2002	1.34	2.66	3.39
2003	1.32	2.57	3.04
2004	1.50	2.86	3.50
2005	1.51	3.08	4.10
2006	1.66	3.15	3.77
2007	1.73	3.30	4.55

UK

Regulation

Extracts from: Evaluation of the implementation of radiation protection measures for aircrew, *Radiation Protection No. 159, European Commission, 2009*

In UK the radiation protection for air crew members is regulated in *The Air Navigation (Cosmic Radiation) Order 2000 (Statutory Instrument 2000 No. 1104)*5 (ANO). The relevant parts are reproduced in the following:
"(...)
Protection of air crew from cosmic radiation
" 65A. - (1) A relevant undertaking shall take appropriate measures to -
(a) assess the exposure to cosmic radiation when in flight of those air crew who are liable to be subject to cosmic radiation in excess of 1 Millisievert per year;
(b) take into account the assessed exposure when organising work schedules with a view to reducing the doses of highly exposed air crew; and
(c) inform the workers concerned of the health risks their work involves.

(2) A relevant undertaking shall ensure that in relation to a pregnant air crew member, the conditions of exposure to cosmic radiation when she is in flight are such that the equivalent dose to the foetus will be as low as reasonably achievable and is unlikely to exceed 1 Millisievert during the remainder of the pregnancy.

(3) Nothing in paragraph (2) shall require the undertaking concerned to take any action in relation to an air crew member until she has notified the undertaking in writing that she is pregnant.

Keeping and production of records of exposure to cosmic radiation
67. - (1) A relevant undertaking shall keep a record for the period and in the manner prescribed of the exposure to cosmic radiation of air crew assessed under article 65A and the names of the air crew concerned.

(2) A relevant undertaking shall, within a reasonable period after being requested to do so by an authorised person, cause to be produced to that person the record required to be kept under paragraph (1).
(3) A relevant undertaking shall, within a reasonable period after being requested to do so by a person in respect of whom a record is required to be kept under paragraph (1), supply a copy of that record to that person."

Data

Extracts from: Ionising Radiation Exposure of the UK Population: 2005 review, *HPA-RPD-001*

Exposure from cosmic radiation will be dependent on the number of hours that aircrew spend airborne. A survey carried out by NRPB showed that crew on long-haul flights might be airborne for up to about 900 hours per year, while crew on short haul flights might be airborne for up to 400 hours per year. With an average

dose rate from cosmic radiation of 4 µSv/h this implies annual doses up to 1.6 and 3.6 mSv for short and long haul staff respectively. Taking an average flight time of around 600 hours per years would imply an annual dose of 2.4 mSv.

The study quoted above was based on data received from many air operators. A study carried out for British Airways indicated average doses for the various fleets between 0.99 and 2.61 mSv in 2001, with the average of all fleets being about 1.6 mSv. This was lower than normal, due to the grounding of Concorde from August 2000 until November 2011. Considering the two estimates of average doses given here, an overall average annual dose for all aircrew is estimated as 2 mSv. With approximately 40,000 flight deck and cabin crew in the UK, this average annual dose implies an annual collective dose of 80 man.Sv, which is higher than the value given in the previous review, due to the use of a more representative number of aircrew.

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