

COSMIC RADIATION EXPOSURE OF AIRCREW: EPIDEMIOLOGICAL STUDIES

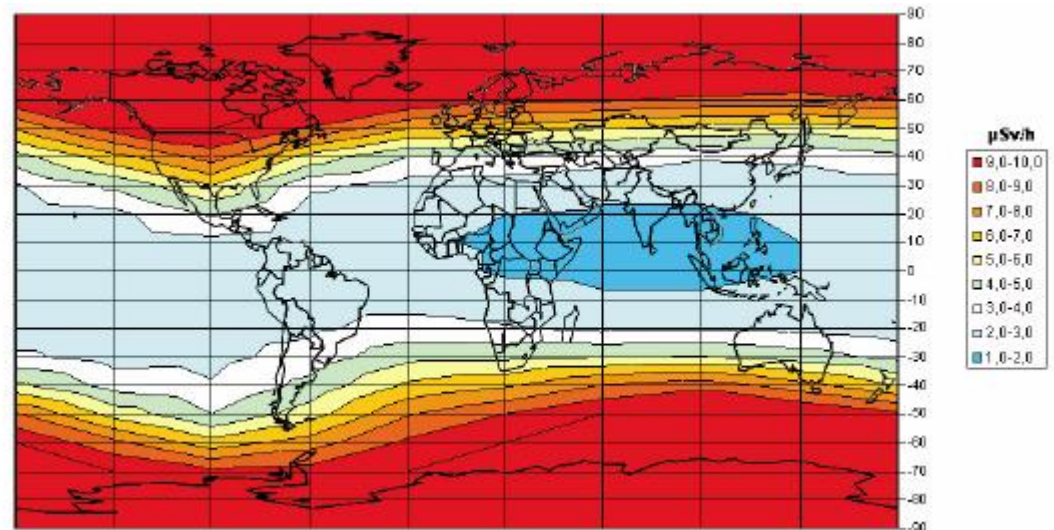
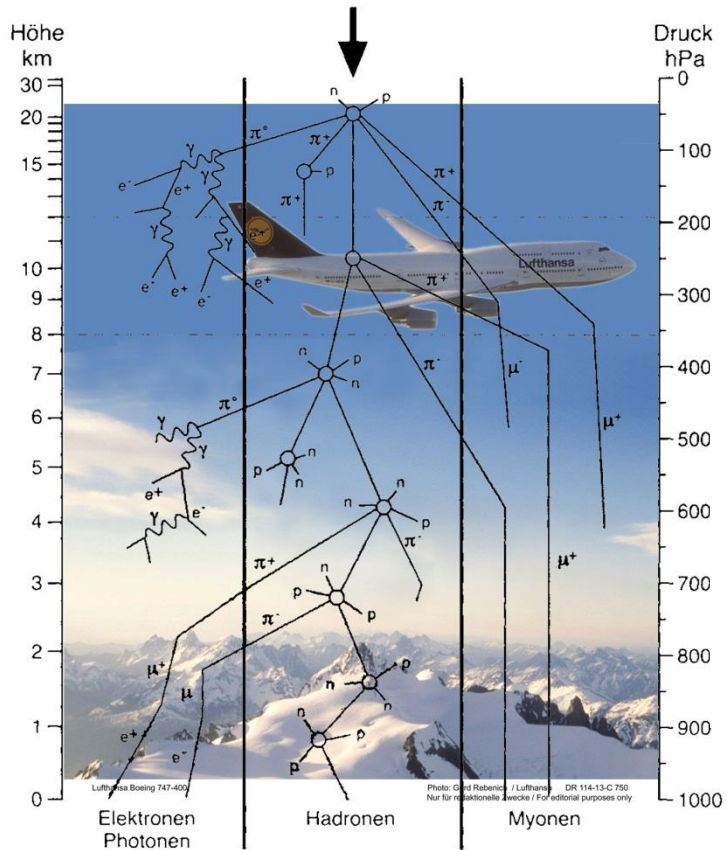
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Tenth European Space Weather Week
22 November 2013, Antwerp, Belgium

- Cosmic radiation
- Exposure assessment for aircrew
- Epidemiological studies
 - Mortality and incidence
 - International studies
 - Results from German cohort
- Conclusion

Cosmic radiation

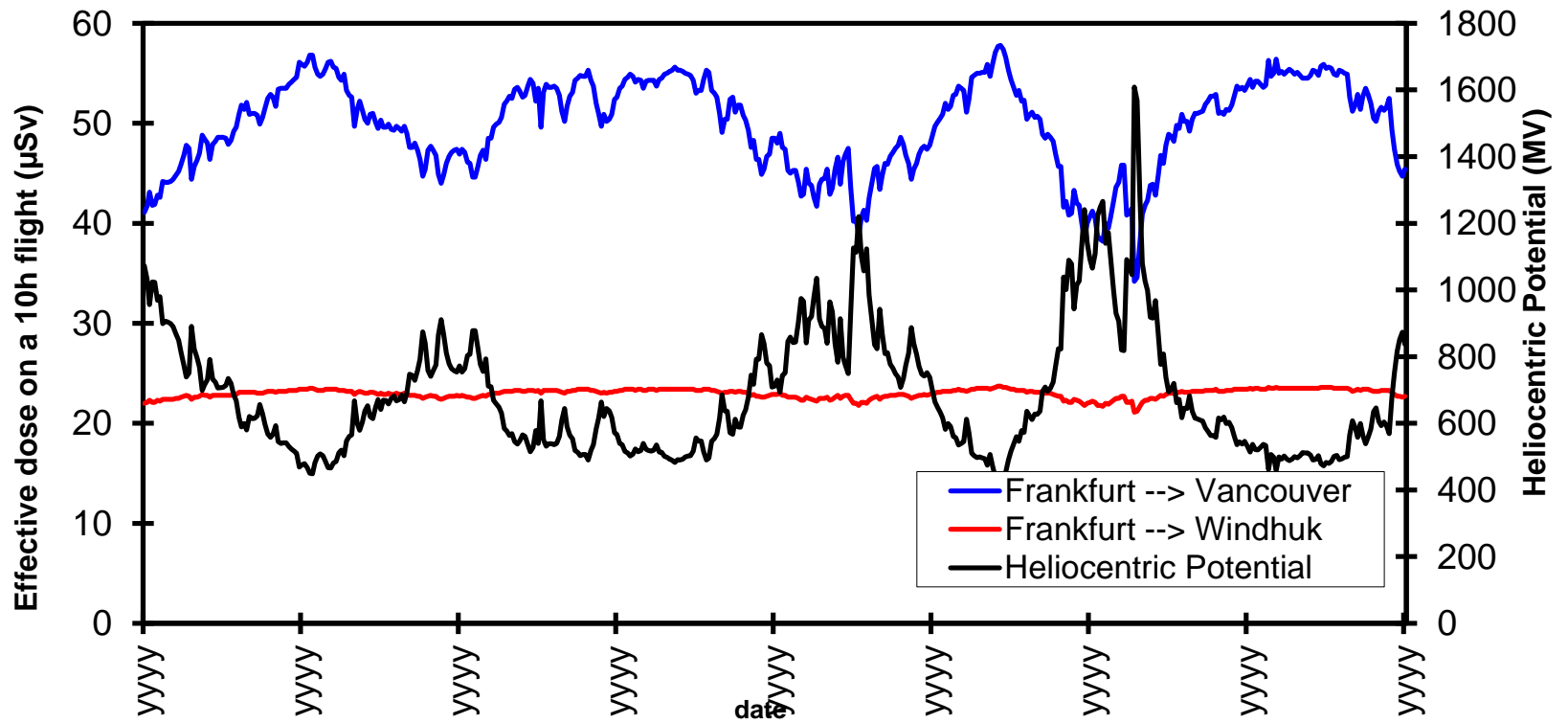


Images from PTB, Braunschweig, and BfS, Salzgitter

Exposure levels

- [effective dose]
- Annually estimated 1.8 – 2.5 mSv
 - Maximum: ~ 6 mSv (London-Tokyo)
- Lifetime: below 100 mSv (additional to background)
 - mean in current studies: ~ 20 mSv
- ... *at (or below) the limits of epidemiology*
- Epi studies do not include exposure information on particle events

11-year solar cycle



Exposure assessment for aircrew

- No personal measurements
- Based on:
 - Individual licences, types of aircraft used
 - Flight details (times, altitudes, direction)
 - Frequency of different flights per time period
 - Information on radiation levels, implemented in specific software programmes, e.g.
 - CARI (US)
 - EPCARD (Europe)

Firefox | EPCARD-Portal: Dosisberechnung auf... | European Program Package for the C... | +

http://www.helmholtz-muenchen.de/epcard/eng_fluginput.php

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EPCARD

Please enter the date, the flight data, and the airports of origin and destination. You may choose a flight profile with up to 12 different flight altitudes.

Date: 2011 Flight number:

Departure airport:

Duration of ascent: hh:mm

To first flight altitude: meter

Duration of descent: hh:mm

Destination airport:

Definition of flight profile:

E-mail:



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Windows taskbar: Start, Internet Explorer, Firefox, VLC, File Explorer, Calculator, PowerPoint, Word, Firefox

System tray: DE, 77% battery, 13:18, 25.08.2011

Confounder, Bias

- Other relevant occupational exposures
 - UV, engine fumes, pesticides, EMF
 - [Medical irradiation]
- Lifestyle, smoking etc.
- Reproductive health
 - Little data available (e.g. Kojo et al. 2005)
- Healthy worker effect
 - Very strong selection, ongoing (annual licence renewal)

ESCAPE - European Studies of Cancer Among flying Personnel

- Low doses: small potential increases in risk
- Increase power by large study size
- European cooperation, 9 countries
 - (Denmark, Finland, Germany, Greece, Iceland, Italy, Norway, Sweden, United Kingdom)
- Retrospective cohort mortality studies
- Follow-up 1960 – 1997 (some variations)

ESCAPE: Cohorts

Country	Data sources	Cohort inclusion	Cockpit		Cabin	
			male	female	male	female
Denmark	Natl. Clinic for Aviation Medicine, Aviation Authority	1946 - 1996	3814	92	1264	4739
Finland	Finnish Airline Pilots Association, Finnair	1921/47 - 1997	782	10	187	1556
Germany	Deutsche Lufthansa, LTU	1953 - 1997	6061	89	4537	16014
Greece	Olympic Airways	1946 - 1997	843	-	620	1215
Iceland	Natl. Aviation Authority, Airline Pilots Association	1935 - 1997	438	-	143	1313
Italy	Alitalia	1965 - 1995	3020	6	3162	3015
Norway	Civil Aviation Admin.	1947 - 1996	3664	63	573	3066
Sweden	SAS Sweden	1957 - 1994	1405	-	593	2145
UK	British Airways	1950 - 1997	7770	-	-	-
ESCAPE			27797	260	11079	33063

Exposure assessment: Job-Exposure-Matrix

Job history x **Job-Exposure-Matrix** = **estimated radiation dose**

PK 50 319 F Name [REDACTED] Flugstunden

Muster	F/i Lockheed ^{1049/249}	F/i B707	F/i DC10	FE B747	
Vorjahre	910	3.647	2.004		
1978			290		
1979			377		
1980			446		
1981			510		
1982			445		
1983			440		
1984			456		
1985			319		
1986			212		
1987			377		
1988				354	
1989				312	
1990				269	
1991				333	
Total	910	3647	5876	1268	

Cumulative doses:

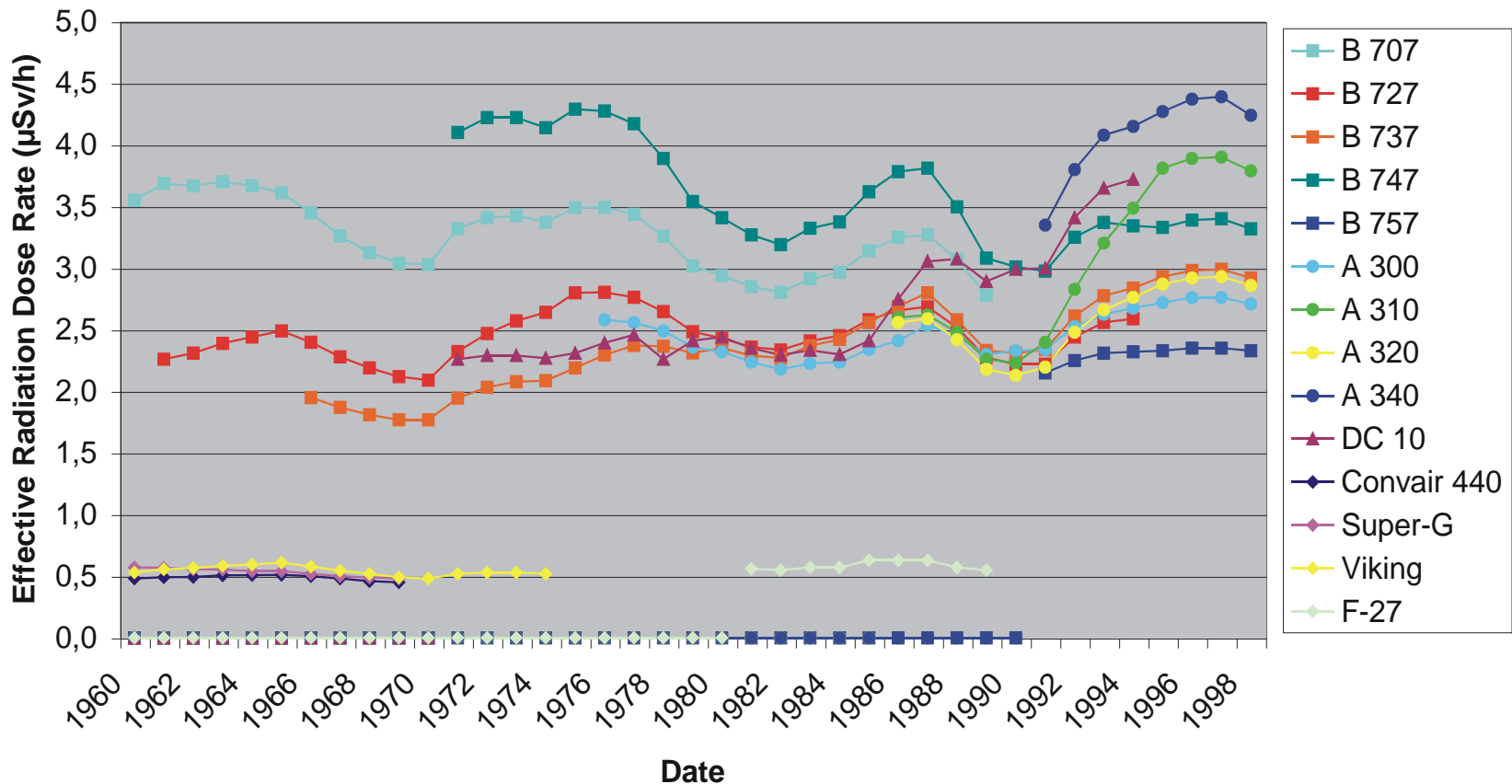
retired pilots:
42 mSv

active pilots:
20 mSv

Max. lifetime:
~ 80 mSv

Job Exposure Matrix (JEM) – “dose rate” per aircraft type

Job Exposure Matrix for Lufthansa cohort
computed from flight schedules with CARI-5E



ESCAPE study: cancer mortality

Cause of death	Cockpit, Men			Cabin, Men			Cabin, Women		
	O	SMR	95% CI	O	SMR	95% CI	O	SMR	95% CI
All cancer	677	0.68	0.63 - 0.74	119	0.90	0.74 - 1.12	440	0.80	0.73-0.88
Buccal cavity/pharynx	13	0.54	0.29 - 0.95	9	1.70	0.77 - 3.43			
Large intestine	64	1.07	0.81 - 1.38	5	0.71	0.23 - 1.75	7	0.65	0.26 - 1.42
Rectum	30	0.80	0.54 - 1.16	3	0.72	0.15 - 2.24	3	0.58	0.12 - 1.88
Lung	153	0.53	0.44 - 0.62	24	0.75	0.47 - 1.17	17	0.82	0.48 - 1.41
Malignant melanoma	25	1.78	1.15 - 2.67	6	1.93	0.70 - 4.44	2	0.36	0.04 - 1.37
Breast							59	1.11	0.82 - 1.48
Prostate	54	0.94	0.71 - 1.26	5	1.09	0.35 - 2.68			
CNS	41	1.20	0.87 - 1.67	6	0.94	0.33 - 2.11	7	0.67	0.27 - 1.49
All lymphoma	25	0.75	0.48 - 1.13	11	1.86	0.92 - 3.50	8	1.06	0.44 - 2.18
Non-CLL leukemia	21	1.12	0.67 - 1.70	5	1.57	0.50 - 3.81	7	1.20	0.49 - 2.73

ESCAPE study: risk trends with dose (cockpit)

		Cumulative Dose (mSv)				P (Trend)
		0-4.9	5.0-14.9	15.0-24.9	25.0+	
All causes	Cases	493	298	287	156	
	RR	1	0.68 (0.58-0.78)	0.71 (0.61-0.83)	0.54 (0.45-0.66)	<0.0001
All cancers	Cases	105	74	93	66	
	RR	1	0.75 (0.53-1.05)	0.79 (0.58-1.09)	0.74 (0.51-1.06)	0.101
Radiogenic cancer	Cases	27	21	28	18	
	RR	1	0.81 (0.44-1.47)	0.95 (0.54-1.65)	0.82 (0.43-1.55)	0.645
Leukaemia excl. CLL	Cases	4	5	2	3	
	RR	1	1.56 (0.48-5.04)	0.75 (0.16-3.51)	2.00 (0.49-8.08)	0.567
Malignant melanoma	Cases	5	3	5	1	
	RR	1	0.71 (0.23-2.18)	1.26 (0.45-3.50)	0.33 (0.06-1.85)	0.481

Recent analyses

2nd F/U Germany 1960 – 2004

	N	%
Persons cockpit crew	6006	100
Deaths until 1997 (first follow up)	255	4.2
Deaths until 2004	405	6.7
Emigrated	356	5.9
Lost to follow up	65	1.1
Alive	5180	86.2
and still active at end of follow up	3262	54.3
Person-years	141303.5	
Mean follow up (years)	23.5	
Mean age at end of follow up	51.5	

RR per categories of cumulative exposure

Cause of death	Cumulative effective dose (mSv)	Latency period: 10 years				No latency period			
		Cases	RR	95% CI	P-trend*	Cases	RR	95% CI	P-trend*
All cancer	0	5	0.42	0.15, 1.18	0.07				0.02
	>0-4.99	14	1.00	0.51, 1.95		8	0.89	0.38, 2.07	
	5-14.99	24	1.00	(ref.)		18	1.00	(ref.)	
	15-24.99	47	1.71	1.03, 2.85		39	1.57	0.89, 2.77	
	25+	37	1.22	0.68, 2.18		62	1.81	1.01, 3.23	
Radiation associated cancer	0	2	0.38	0.07, 1.97	0.56				0.64
	>0-4.99	1	0.17	0.02, 1.32		1	0.27	0.03, 2.21	
	5-14.99	10	1.00	(ref.)		7	1.00	(ref.)	
	15-24.99	12	1.01	0.42, 2.43		12	1.23	0.48, 3.19	
	25+	8	0.54	0.19, 1.56		13	0.80	0.29, 2.17	
Non radiation - associated cancer	0	3	0.45	0.12, 1.67	0.08				0.01
	>0-4.99	13	1.60	0.74, 3.44		7	1.31	0.50, 3.43	
	5-14.99	14	1.00	(ref.)		11	1.00	(ref.)	
	15-24.99	35	2.22	1.17, 4.21		27	1.80	0.88, 3.65	
	25+	29	1.73	0.85, 3.54		49	2.57	1.25, 5.29	

CNS cancer: non-significant 18% risk increase per 10 mSv

COSMIC – 2nd Follow-up of ESCAPE

- Extended follow-up of the cohort until 2004
 - Includes PAN AM cohort
 - mean follow-up: 21.7 years
 - 5508 deaths [28.8% more cases included (20.5% cockpit (men), 27.9% and 48.8% male and female cabin crew, respectively)]
 - overall mortality does not appear to increase with increasing employment duration
 - Results published soon (under review)

- Cabin attendants
 - Pukkala et al., 1995 (Finland)
 - Reports increased breast cancer incidence (SIR = 1.87)
 - Reynolds et al, 2002 (California, USA)
 - Breast cancer SIR ~ 1.3
 - Pukkala et al. 2012 (Nordic countries)
 - Breast cancer SIR = 1.5 (1.32-1.69)
- Pilots (No-ESCAPE)
 - Pukkala et al. (2002, 2003)

RR per cumulative dose, Nordic countries

Cumulative dose (μSv)	All sites*		Skin melanoma	
	No	Relative risk	No	Relative risk
1-2999	149	1 (reference)	14	1 (reference)
3000-9999	52	1.12 (0.81 to 1.53)	9	2.10 (0.91 to 4.87)
10 000-19 999	93	1.19 (0.92 to 1.54)	13	2.20‡ (1.03 to 4.72)
$\geq 20\ 000$	137	1.19 (0.93 to 1.51)	17	2.78‡ (1.30 to 5.93)
P trend		0.13		0.007

Cumulative dose (μSv)	Other skin*		Basal cell carcinoma†		Leukaemia, excluding chronic lymphatic	
	No	Relative risk	No	Relative risk	No	Relative risk
1-2999	7	1 (reference)	7	1 (reference)	3	1 (reference)
3000-9999	1	0.52 (0.06 to 4.26)	6	1.83 (0.70 to 4.79)	2	1.90 (0.32 to 11.5)
10 000-19 999	6	1.50 (0.50 to 4.48)	8	1.42 (0.60 to 3.41)	2	1.42 (0.23 to 8.70)
$\geq 20\ 000$	12	1.92 (0.74 to 4.98)	32	1.86 (0.98 to 3.54)	3	1.78 (0.32 to 10.0)
P trend		0.14		0.17		0.53

*Excludes basal cell carcinoma and, in Denmark, all non-melanoma skin cancers diagnosed before 1979.

†Only Denmark (1979-96) and Finland (1953-97).

‡Significant at $P < 0.05$.

From Pukkala et al, 2002

Other impacts...

Circadian rhythm changes

- Carcinogenic effects of shift work under discussion
 - IARC: IIa classification (2007)
- Major part of evidence from aircrew
 - mainly long-haul, crossing time zones

Cytogenetics

- studies of cytogenetic changes in crew

Conclusion

- Aircrew cosmic radiation doses roughly comparable to doses in nuclear industry
 - Only small risk increases to be expected a priori
 - Factors influencing risk are somewhat difficult to disentangle, e.g. circadian rhythm changes
- Current evaluation: no clear health risks associated with exposure to cosmic radiation
 - ? Breast cancer, melanoma ?
 - Options for further cytogenetic studies ?
- Extended (third) follow-up for the German cohort starting 2014

Thank you

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