

Epidemiological investigations of aircrew

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Structure

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- ESCAPE study design
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Introduction

Regulative Aspects

- ICRP recommends to consider flying personnel as occupationally exposed (1991)
- European Council Directive 92/29/EURATOM (1996)
- Implementation in National Radiation Protection Regulations (Germany: 2000)

Scientific interest

- Effects of neutron radiation
- Low dose effects

Concerns of employees: Radiation Risk?

Introduction

Occupational exposures of aircrew

- Cosmic radiation
- Electromagnetic fields
- Turbine exhausts
- Circadian rhythm disruptions, shift work
- Passive smoking (in the past)
- Pesticides

Other risk factors

- Life-style factors (UV, Alcohol)
- Reproductive factors

Pre-ESCAPE - SMR for pilots

	Band et al., 1990	Kaji et al., 1993	Band et al., 1996	Irvine et al., 1999
Company	CP Air	Japan Airlines	Air Canada	British Airways
Period	1950 - 1988	1952-1988	1950 - 1992	1950 - 1992
Persons	913	2327	2740	6209
Pers.-years	18,060	~30.000	62,449	143,506
deaths	71	59	219	592
cancers	16	20	56	180

Pre-ESCAPE - SMR for pilots

Tumor	Band et al., 1990	Kaji et al., 1993	Band et al., 1996	Irvine et al., 1999
All	0.80*	0.87	0.63*	0.61*
Rectum	4.35*	-	-	0.66*
Brain	4.17*	-	1.42	1.28
Lung	0.52	-	0.25*	0.42*
Leukaemia	-	-	0.86	-
Prostate	-	-	1.52	1.11
Melanoma	-	-	1.49	3.33*

* Statistically significant

Incidence Studies

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

Other studies

■ Band et al, 1990, 1996

ESCAPE

European Studies of Cancer Among flying PErsonnel

- ❑ Low doses: small potential increases in risk
- ❑ Maximise power by large study size
- ❑ European cooperation, 9 countries
 - (Denmark, Finland, Germany, Greece, Iceland, Italy, Norway, Sweden, United Kingdom)
- ❑ Coordination: German group
- ❑ Cohort studies with very similar design
- ❑ F/U 1960 - 1997 (some variations)

ESCAPE: Statistical methods

- External comparisons (SMR)
 - Correcting for missing causes of death
 - Stratified Analyses
- Internal comparisons to assess dose trends(RR)
 - Poisson-Regression
- Incidence studies in Nordic countries (NoESCAPE)

Dosimetry: Job-Exposure-Matrix (JEM)

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

PK _____ Name _____ Flugstunden

Muster	F/i LOCKHEED ^{1049/2649}	F/i B707	F/i DC10	FE B747	
Vorjahre	910	3.647	2.004		
1978			290		
1979			377		
1980			446		x r $\mu\text{Sv/h}$ = Dose
1981			510		
1982			445		
1983			440		
1984			456		
1985			319		
1986			212		
1987			377		
1988				354	
1989				312	
1990				269	
1991				333	
Total	916	3647	5876	1268	

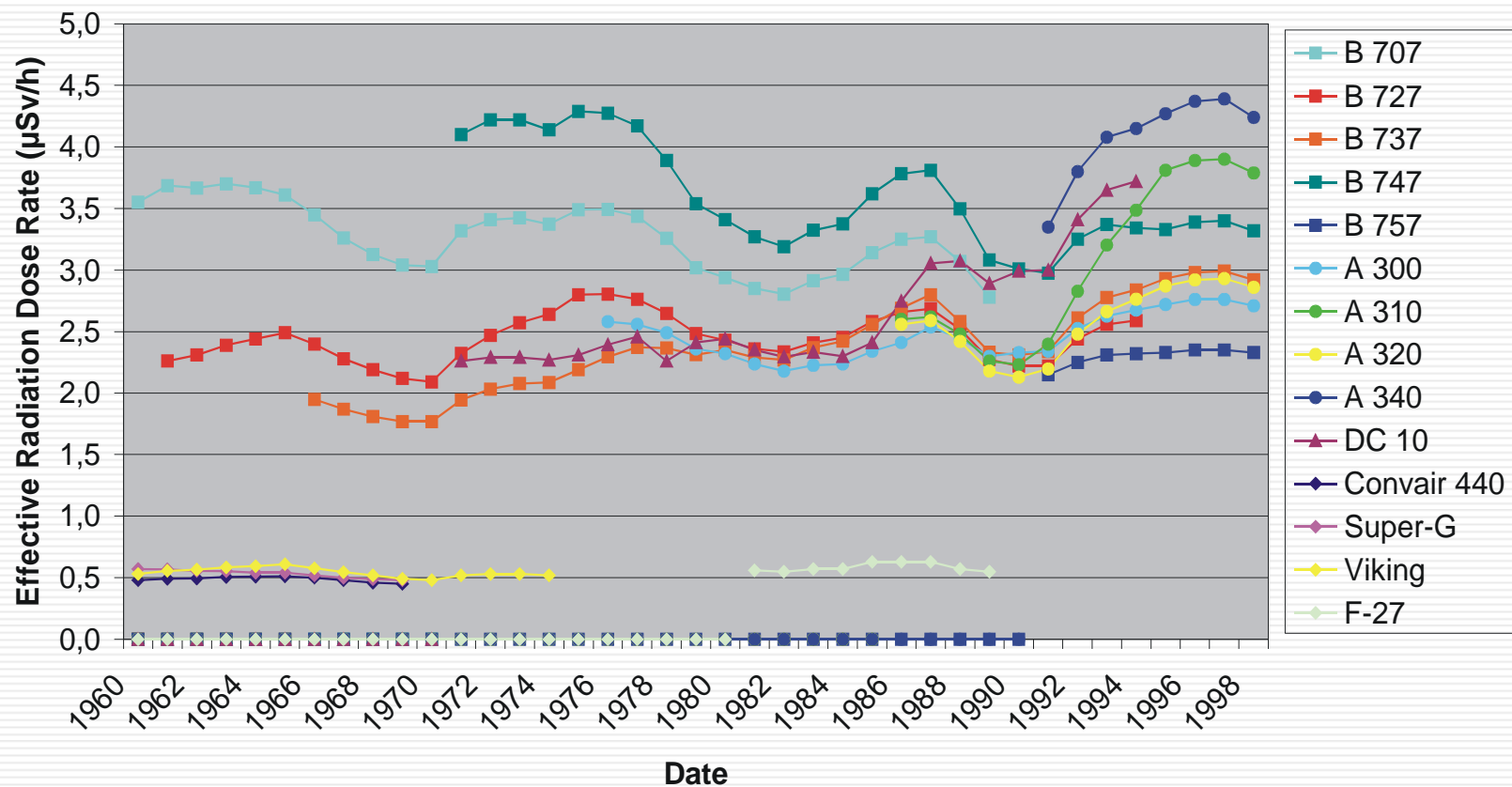
Form 4458 B-78 (FRA NV 1) Printed in Germany

Dosimetry for ionising radiation

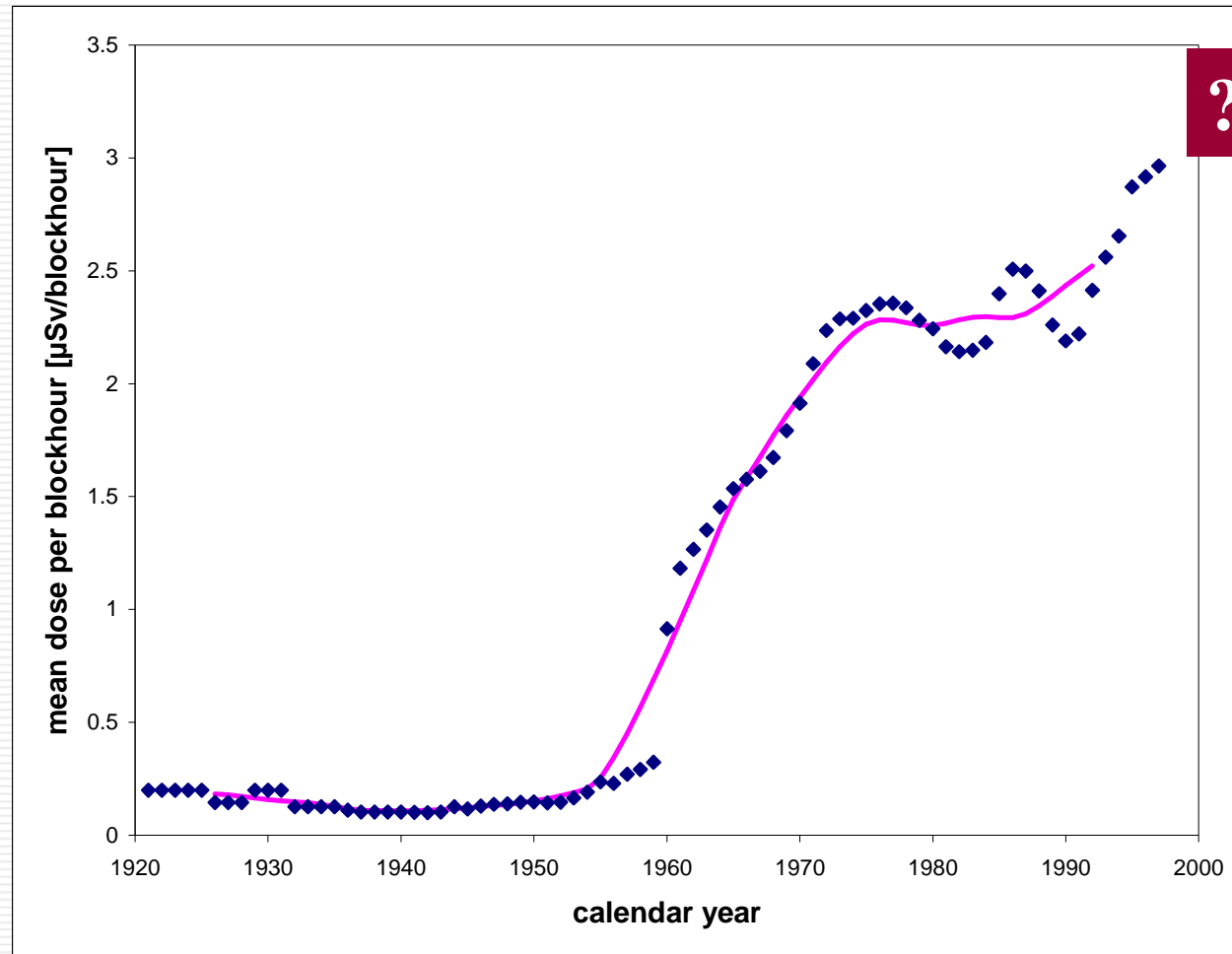
- Job-Exposure-Matrix
 - $\mu\text{Sv}/\text{Block hour}$, per year and aircraft type
 - Computed with CARI 6 (US FAA)
 - Using published flight schedules
- Median cumulative dose of German pilots
 - retired pilots (as of 1997): 42 mSv
 - active pilots: 20 mSv
 - Max. lifetime: ~ 80 mSv

Job-Expositions-Matrix (JEM)

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



Development of dose rates



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	Finish Airline Pilots Association, Finair	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

ESCAPE: Deaths

Country	Cockpit		Cabin	
	male	female	male	female
Denmark	268	1	142	115
Finland	50	0	9	15
Germany	255	0	171	140
Greece	65	0	13	13
Iceland	47	0	0	24
Italy	212	0	117	47
Norway	318	1	67	54
Sweden	91	0	53	33
United Kingdom	945	0	-	-
Total	2251	2	571	442

ESCAPE: Duration of employment

Total years of employment	Cockpit		Cabin	
	Men	Women	Men	Women
<1 year	463	15	480	1341
1-<10 years	10677	217	5627	20695
10-<20 years	5553	26	2503	7345
20-<30 years	8020	2	1871	3292
30 years +	3102	-	599	393

ESCAPE: SMR(1)

Cause of death	Cockpit, Men			Cabin, Men			Cabin, Women		
	O	SMR	95% CI	O	SMR	95% CI	O	SMR	95% CI
All causes	2244	0.64	0.61 - 0.67	571	1.09	1.00 - 1.18	441	0.80	0.73 - 0.88
All cancer	677	0.68	0.63 - 0.74	119	0.90	0.74 - 1.12			
All cardiovascular disease	534	0.51	0.46 - 0.56	66	0.62	0.48 - 0.83	13	0.27	0.14 - 0.49
Liver cirrhosis	45	0.56	0.40 - 0.75	18	0.78	0.46 - 1.29	11	0.63	0.31 - 1.21
Motor vehicle accidents	62	0.70	0.53 - 0.90	26	0.76	0.48 - 1.15	24	1.05	0.63 - 1.58
Aircraft accidents	244	87.73	76.5 - 100.8	17	24.70	13.8 - 41.0	31	59.00	38.5 - 86.9
All other external causes	236	0.68	0.59 - 0.78	86	0.80	0.63 - 1.02	106	1.14	0.90 - 1.42
Suicide	73	0.63	0.48 - 0.79	39	1.09	0.76 - 1.54	49	1.19	0.85 - 1.63
HIV/AIDS				118	19.6	15.2 - 23.3			

ESCAPE: SMR(2): Cancer

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			
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: RR for pilots

		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

NoESCAPE: Incidence (SIR)

	Cockpit		Cabin			
			Men		Women	
All Cancer	1.0	(0.9-1.1)	1.5	(1.2-1.8)	1.1	(1.0-1.2)
Melanoma	2.3	(1.7-3.0)	3.3	(1.8-5.8)	2.0	(1.5-2.8)
Leukaemia	1.2	(0.7-2.0)	1.2	(0.2-8.7)	2.0	(1.1-3.4)
Colon	0.9	(0.6-1.3)	0.8	(0.1-0.3)	1.0	(0.3-3.5)
Breast					1.4	(1.1-1.6)

Simple meta analysis. NoESCAPE-publication to appear soon.

Summary

- Occupational radiation exposures are roughly comparable to those in the nuclear industry
 - Only small risk increases to be expected a priori
- Scarce evidence for specific occupational cancer risk

Non-cancer endpoints

- ❑ Melanoma (Iceland, Sweden)
- ❑ Cataract (Iceland)
- ❑ Reproductive health (USA)
- ❑ Mental health, stress (Italy, USA)
- ❑ Cardiovascular health (Sweden)
- ❑ Chromosomal aberrations (latest: NIOSH-NCI study, OEM 2009)
 - finds association of translocation frequency (in lymphocytes) with flight years

Outlook: German cohort: follow-up 31.12.2003

	Cockpit		Cabin		Total
	Male	Female	Male	Female	
Persons	6017	90	3735	17022	26864
deaths 1997	255	0	170	141	566
deaths 2003	385	0	232	266	883 (+56%)
cancer deaths	127	0	45	103	275
lost to follow-up	67	2	96	453	618
emigrated	345	7	302	1339	1993
Person-years	136413	1125	71374	296563	505475 (+46%)
Mean follow-up (yrs)	22.7	12.5	19.1	17.4	18.8

Outlook

- COSMIC (or ESCAPE II)
 - Extended health follow-up of existing cohorts until 31.12.2004 or longer
 - Extended dosimetry data
 - Inclusion of further cohorts (US PAN AM cohort)
 - Relevant increases in case number
- Next update of pooled analyses
 - Additional measure: time zones crossed?
 - Germany
 - Additional use of EPCARD 3.3.4
 - National Dose Registry (since 08/2003)

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- EU (BIOMED) for ESCAPE I
- BfS for COSMIC
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 - BG für Fahrzeughaltungen