



Cancer mortality among German aircrew: second follow-up

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Introduction



- Regulative Aspects
 - ICRP recommends to consider flying personnel as occupationally exposed (1991)
 - European Council Directive (1996)
 - Implementation in National Radiation Protection Regulations (Germany: 2000)
- Scientific interest
 - Effects of neutron radiation
 - Low dose effects
- Concerns of employees: Health Risk?

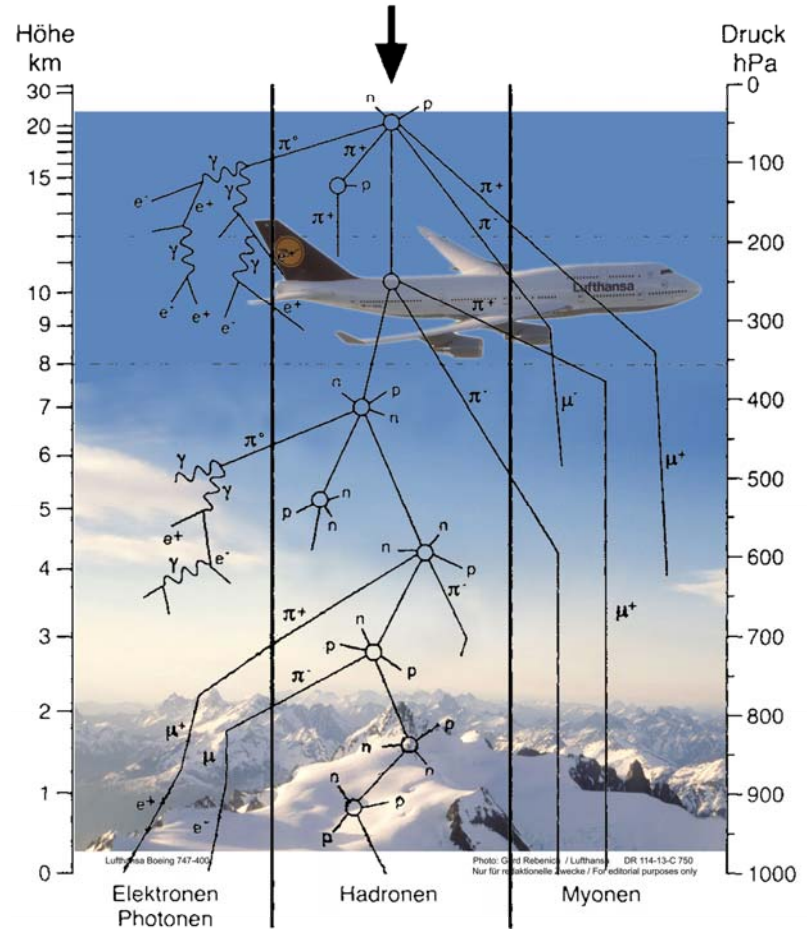
Cosmic radiation exposure

- Primary cosmic radiation generates complex field of secondary particles
- Neutrons dominate effective dose
 - 10% dose, ~ 50% dose equivalent
- Dose rates depend on altitude, latitude, solar cycle
- Range from 1-10 microSv/h
 - 600 – 1000 hours per year typical
- Personal dosimetry
 - not useful / recommended for routine use
 - dose calculation software (CARI, EPCARD, others)

- Tissue equivalent proportional counters



- Bubble detectors



Other “exposures” with potential relevance for cancer risk



Occupational exposures of aircrew

- Electromagnetic fields
- Turbine exhausts, Passive smoking (in the past)
- Circadian rhythm disruptions, shift work
 - IARC 2008: 2A carcinogen
- Pesticides

Other risk factors

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

ESCAPE

European Studies of Cancer Among flying PErsonnel



- Low doses: small potential risk increases
- 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: SMR 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	171	0.78	0.66-0.95
Buc.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
Malig.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

Methods



- Cohort definition
 - All crew identified from personnel records of Lufthansa and LTU International Airways
 - Inclusion 1960 - 1997
 - Cabin crew: minimum ½ year cumulative
 - Cockpit: no limit
 - Limited information of pre-entry flight activity
 - No information on post-exit flight activity

Follow-up and analysis

- All non-deceased cohort members (as of end 1997) followed up via
 - Personnel files (still employed ?)
 - Population registries
 - Public health offices (to obtain death certificates)
 - Intense cohort search to reduce losses

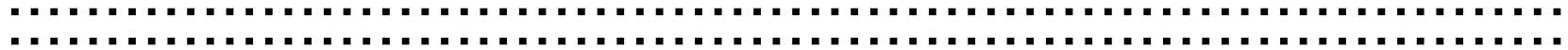
Analysis

- SMR and 95% CI (Ref: German pop.)
- Correction for missing causes of death using a proportional imputation method
 - stratum-specific in stratified analyses
- Poisson regression analysis to estimate effects of duration of employment
 - 0-<10y, 10-<20y, 20-<30y, 30+y
- High correlation *duration-dose* shown previously *

Exposure information



- Duration of employment as aircrew
 - No information on part time employment



- for cockpit: information on licence, type of aircraft, annual individual block hours
- flight schedules of aircraft
 - $\mu\text{Sv}/\text{Block hour}$, per year and aircraft type
- leads to job exposure matrix for an estimate of annual effective dose

Dosimetry: Job-Exposure-Matrix



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

PK _____ Name _____ Flugstunden

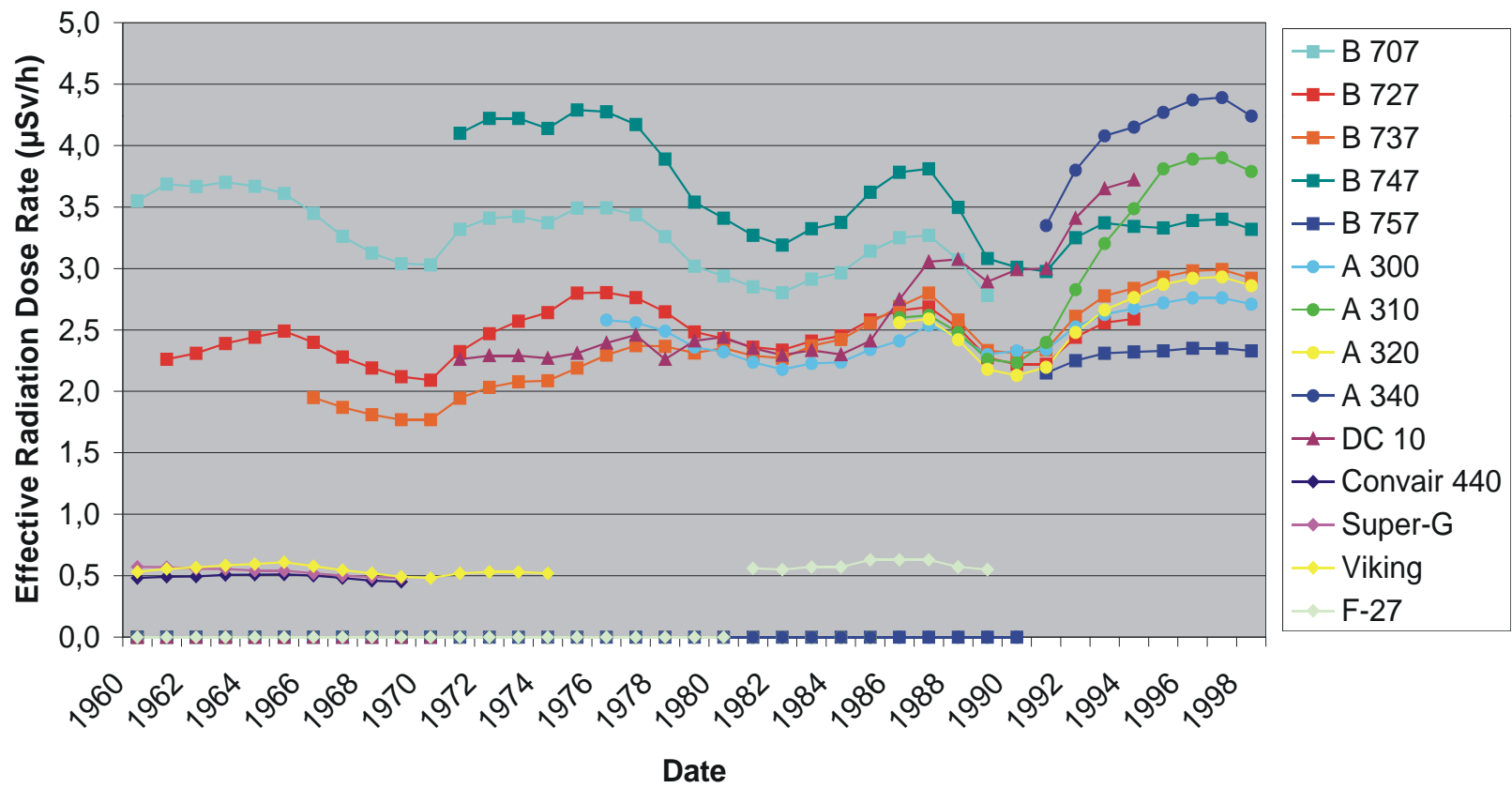
Muster	F/i LOCKHEED ^{104%} 7649	F/i B707	F/i DC10	FE B747	
Vorjahre	910	3.647	2.004		
1978			290		
1979			377		
1980			446		x r $\mu\text{Sv/h}$ = Dose
1981			510		
1982			445		
1983			440		
1984			456		
1985			319		
1986			212		
1987			377		
1988				354	
1989				312	
1990				269	
1991				333	
Total	910	3647	5876	1268	

Form 4458 B-76 (FRA NV 1) Printed in Germany

Job-Expositions-Matrix (JEM)



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



Data up to 1997

- Median cumulative dose of German pilots
 - retired pilots (as of 1997): 42 mSv
 - active pilots: 20 mSv
 - Max. lifetime: ~ 80 mSv
- Same approach used in extended f/u
 - Data protection issues an obstacle
 - Data collection ongoing

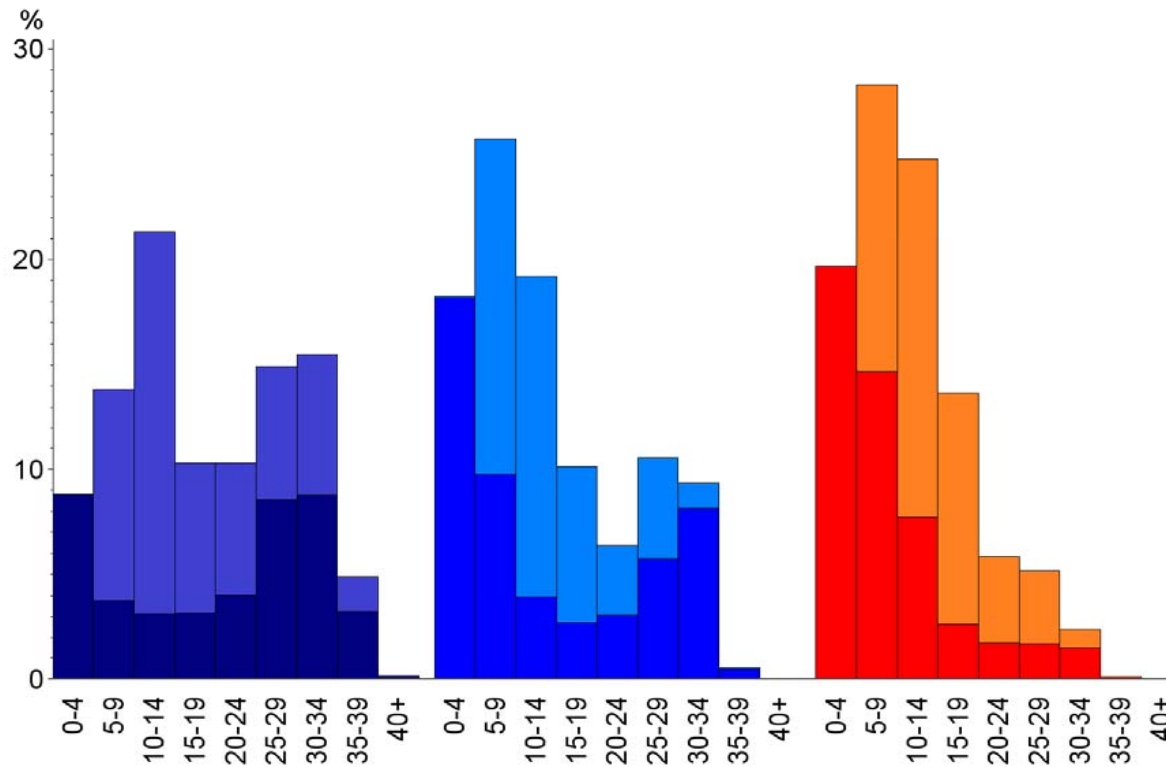
Results German cohort: follow-up to end 2003



	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
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
Mean follow-up (yrs)	22.7	12.5	19.1	17.4	18.8

Missing CoD: Cockpit 6.3%; Cabin 13.6%

Duration of employment



Arithm. mean

not employed

20.18

13.79

8.73

still employed

18.31

14.39

14.58

Standardized Mortality Ratios - Cockpit

- Will be presented in conference-related publication
- Overall:
 - SMR for all cancer reduced,
 - Made reduction of lung cancer SMR
 - Few individual cancers with elevated SMR

Standardized Mortality Ratios – Cabin Crew

- Will be presented in conference-related publication
- Most cancers with non-significant SMRs
 - Includes breast cancer

Discussion

- Large cohort of aircrew
- About 60% increase in cohort deaths from 1997-2003
 - Low overall mortality cockpit (SMR ~ 0.5)
- Follow-up of a mobile group poses difficulties
- Loss to follow-up moderate
 - Missing death certificates continue to be a problem

Exposure

- Outstanding: computation of radiation dose estimates
 - CARI
 - EPCARD software
 - Consider computing ERR per dose

Outlook: 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



- 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)

Acknowledgments



- EU (BIOMED) for ESCAPE I
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Thank you



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