NIOSH Air Crew Studies

Barbara Grajewski, Ph.D.
April 15, 2015

Partners

FAA Kyle Copeland
NASA Christopher Mertens
NOAA David S. Evans
Study airlines and unions

Overview

- Origins/objectives of air crew program
- What sets NIOSH research apart
- Exposures
- Health Studies
  - Exposure assessment of US pilots
  - Miscarriage in Flight Attendants
- Implications

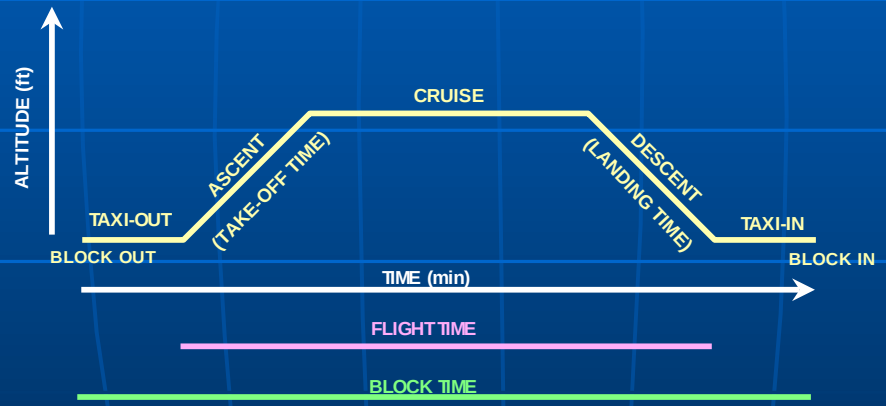
Background

- 200,000 US workers and 500,000 workers worldwide in commercial aircraft cabins
- Other workers with air travel
  - unscheduled business jets
  - air couriers
  - frequent business fliers
  - military
- Air cabin exposures
  - Galactic cosmic (GCR) and Solar particle event (SPE) radiation
  - Circadian rhythm disruption
  - Airborne contaminants
  - Ergonomic factors
  - Stress

NIOSH Approach: Flight Exposure Assessment

- **2.5 M+ Individual flight histories available**
  - Individual flight exposure estimates
  - "Windows of exposure"
  - ⬇ misclassification in epidemiologic analyses

Phases of a Flight Segment

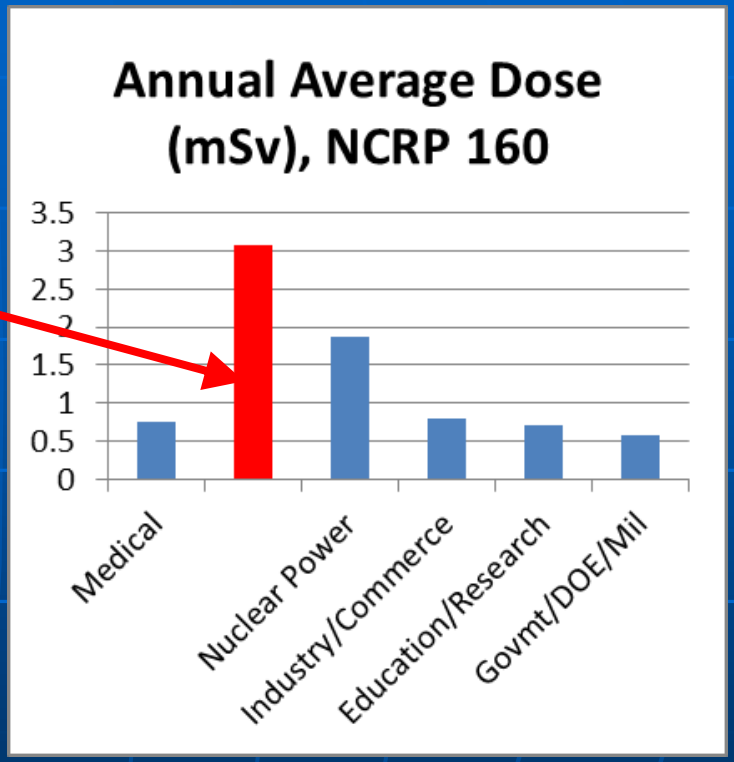


- **Individual flight histories not available**
  - Domicile- era- specific estimates of exposure
  - Link with work histories for individuals' estimates

Occupational Radiation Exposure

- What worker group is most exposed to workplace radiation?

AVIATION



- 250,000 air crew worldwide monitored for radiation
- 0 US air crew monitored for radiation

Ionizing Radiation

- IARC known human carcinogen
- Linked to adverse reproductive outcomes

Exposure Assessment

- 2.5+ M individual flights
- GCR particle and total doses: FAA's CARI 6P
- Evaluate every flight for SPE status
- Solar storm data from NOAA
  - Moderate-large events, approximate S2-S3 range
  - "Date gates" to determine if flight occurred during SPE

Radiation Exposure Assessment

- Estimated SPE doses from NASA's Nowcast of Atmospheric Ionizing Radiation Safety (NAIRAS)
  - Real-time prediction of exposure rates at aviation altitudes
- 2 NAIRAS data sets for each SPE:
  - Dynamic (hour-by-hour) radiation absorbed and effective dose rates covering each storm period
    - 5x5 degree grid at altitudes 0-90 km
    - ~230,000 data points /hour
  - Event-averaged dose rates

SPE Dose Estimation

$$D_{SPE} = D_{CARI} \times \frac{1}{2}\left[\frac{1}{t}\sum_{i=1}^{t}\left(\frac{\dot{D}_{i,SPE}}{\dot{D}_{i,GCR}}\right)_{ori} + \frac{1}{t}\sum_{i=1}^{t}\left(\frac{\dot{D}_{i,SPE}}{\dot{D}_{i,GCR}}\right)_{dest}\right]$$

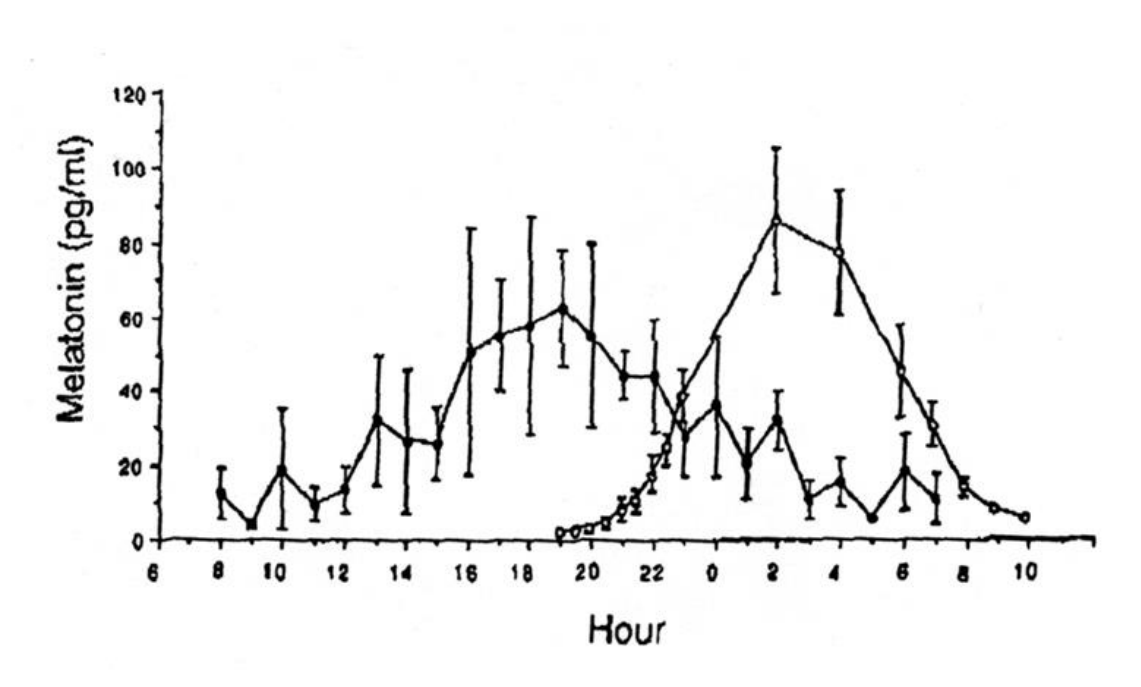
$$D_{SPE} = D_{CARI} \times \frac{1}{2}\left[\left(\frac{\dot{D}_{SPE}}{\dot{D}_{GCR}}\right)_{ori} + \left(\frac{\dot{D}_{SPE}}{\dot{D}_{GCR}}\right)_{dest}\right]$$

Anderson JL, Mertens CJ, Grajewski B et al. Flight attendant radiation dose from solar particle events. Aviat Space Environ Med 2014; 85:828-32.

Circadian disruption:

"The swing shift is the killer"

–Josephine Arendt



- NHS: Night shift work increases risk of fetal loss
- Shift work with circadian disruption: IARC probable human carcinogen

NIOSH Approach

- Monitor sleep and a circadian biomarker
- Identify useful metrics for larger studies

Air Crew Research Program

Health Effect Studies

Reproductive Health
- Ovulatory Function/Menstrual Cycle
- Pregnancy Outcomes

Cancer
- Cytogenetic Effects among Pilots
- Mortality in Flight Attendants and Pilots
- Breast Cancer Incidence among Flight Attendants

Other
- Respiratory Symptoms
- Effects of Downsizing on Mortality

Exposure Studies

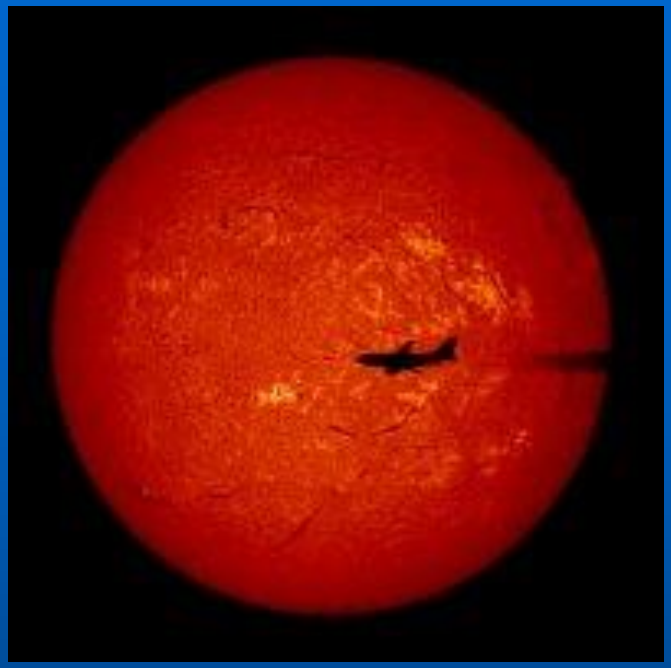
Radiation
- GCR and SPE Radiation
- Retrospective Estimation of Dose

Cabin Air Quality
- Cabin Environmental Exposures
- Bioaerosol Levels in Aircraft

Other Factors
- Physical Work Demands
- Psychosocial Work Conditions
- Circadian Rhythm Disruption

Completed

Ongoing



Exposure assessment for the NIOSH study of chromosomal aberrations in pilots

Graphics courtesy of Kanzelhöhe Observatory and CR Mitchell et al. (Radiat Res 2004;162:257-63).

Grajewski B, Waters MA, Yong LC et al. Airline pilot cosmic radiation and circadian disruption exposure assessment from logbooks and company records.

Editor's Choice, Ann Occ Hyg 2011; 55: 465–475 and online supplement

Design

- 83 full time male pilots from a major US airline
- Data extracted/imputed from pilot records 1963-2003
  - Airline records
  - Pilot logbooks
  - Summary records
  - Commuter travel
  - Recreational (“pass”) travel
  - Questionnaire
- Radiation and circadian disruption assessed
  - GCR: FAA’s CARI6P, CARI6PM
  - SPEs: binary exposure based on equipment, geomagnetic latitude, and NOAA satellite data
  - Time zones crossed and time spent working during normal sleep hours

Results

- A hypothetical (median) pilot incurred a cumulative radiation dose of 34.4 mSv, with 1.9 mSv in the last study year.
- Pilots incurred possible SPE exposure a median of 6 times (range 1-14), or once every 3.7 years of work (range 1.6 – 16.8 y).
- Dose and circadian disruption metrics were only moderately correlated with years of flying.
- Median doses and circadian disruption metrics per flight segment rose markedly from the 1990s to 2003 (p_{trend} <0.0001).

Impact

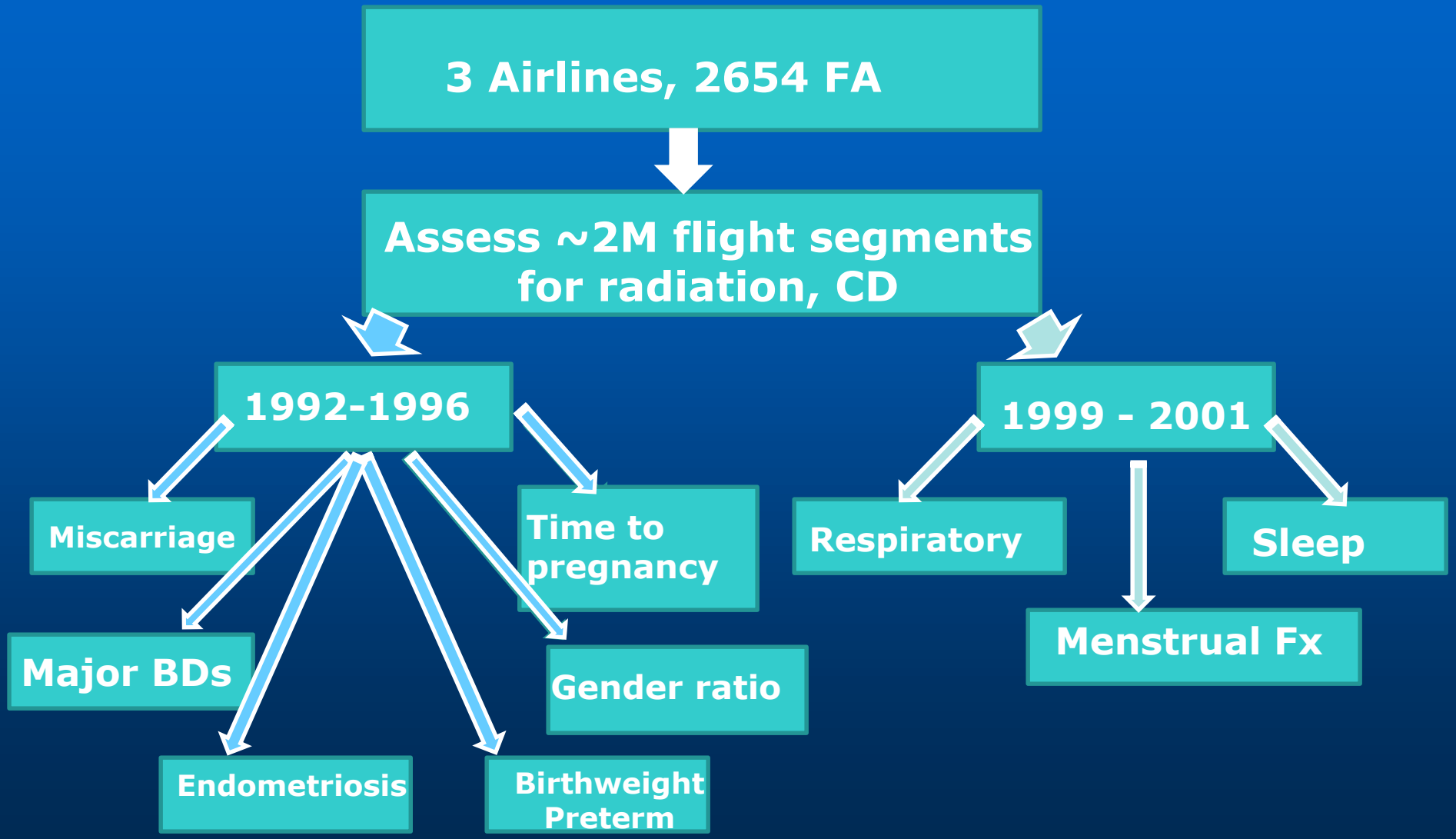
This is the first study to report

- Air crew career exposure assessment from individual flight segments
- Long-term assessment of circadian disruption in air crew
- Assessment of cumulative solar particle event exposure.

Flight Attendant Reproductive Risks

- Flight attendants may experience increased risk of:
  - Miscarriage
  - Menstrual disorders
  - Other adverse reproductive outcomes
- Is work as a female flight attendant associated with adverse reproductive effects?

Reproductive Outcomes Questionnaire Study



Exposure assessment

1.9M company records of individual flights

Questionnaire data for each pregnancy

Exposure assessment

Time-dependent exposure metrics for each week of pregnancy

- **GCR and SPE radiation**
- **Time zones crossed**
- **Work during normal sleep hours**

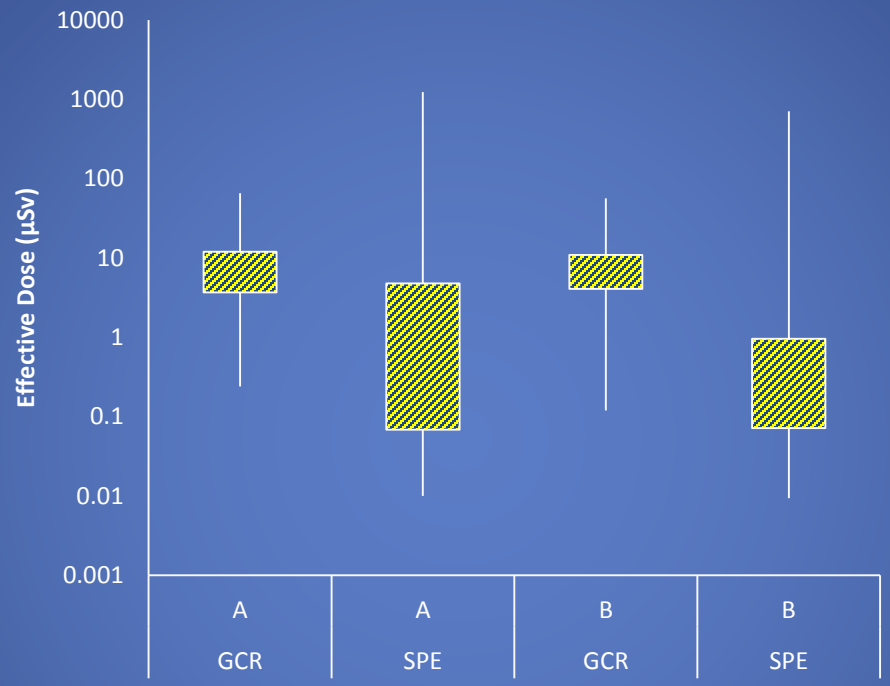
Fixed workplace exposure metrics

- **Physical job demands**
- **Passive smoking**
- **Psychosocial stressors**

Analysis

- Cox Proportional Hazards regression, discrete time data

SPE Dose Estimation



Effective dose per flight segment from GCR and SPE radiation for study period A (1411 flight segments) and study period B (6593 flight segments). Lines indicate data ranges (min, max) and boxes indicate interquartile ranges. Only segments with significant (nonzero) estimated SPE dose are represented.

Grajewski B, Whelan EA, Lawson CC, Hein MJ, Waters MA, Anderson JL, MacDonald LA, Mertens CJ, Tseng C-Y, Cassinelli II RT, Luo L. Miscarriage in flight attendants. Epidemiology 2015;26:192–203.

Results

- 2654 women interviewed, 87% participation; 958 pregnancies analyzed
- Miscarriage in the first trimester was 50% more likely for a pregnant flight attendant who flew 15 hours or more during her normal sleep hours (OR=1.5; 95% CI=1.1 – 2.2).
- Miscarriage in the first trimester was about 2.5 times as likely for a pregnant flight attendant with high physical job demands (OR=2.5; 95% CI=1.5 – 4.2).
- There is evidence that cosmic radiation dose of 0.1 mGy or more in the first trimester increases the risk of miscarriage by 70% (OR=1.7; 95% CI=0.95 – 3.2).
- 2% of study pregnancies were exposed to an SPE. The two highest study SPE exposures were 1.2 and 0.8 mSv, both from single flights.

Strengths

- First assessment of flight attendant radiation and circadian disruption from individual flight records
- First direct estimation of SPE radiation dose in flight attendants

Implications

- Circadian disruption and ergonomic guidelines being developed for pregnant workers should be adapted for pregnant air crew.
- Flying 1-2 flights during an SPE could exceed ICRP, NCRP pregnancy guidelines/limits.
- 50% of our flight attendants had estimated annual effective doses of 1.5 – 4.9 mSv prior to pregnancy.
- There are no official dose limits and no mandatory training for this most highly exposed group of radiation workers in the United States.

US: Future Directions

- Air crew radiation exposures are occupational exposures
- Clarify regulatory responsibility for air crew occupational exposures
- Optimize protection: focus on highest exposed
- Implement management systems for dose estimation and recordkeeping
- Implement air crew exposure training & education

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health

NEW!

NIOSH aircrew health & safety webpages

http://www.cdc.gov/niosh/topics/aircrew/

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health