Aircrew exposure to cosmic rays
- Challenges and management -

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Content

Cosmic radiation as existing exposure

Physical, economical and social impacts

Aviation and optimization

Globalisation and future challenges
High altitude radiation

Cruising altitudes: 10 - 15 km

- Protons (> 1 GeV)
- Pions, Neutrons
- Myons
- Elektrons
- Neutrinos
- Gamma
Solar activity in solar cycle 23 and 24
Geo-magnetic shielding of cosmic ray

Ambient dose rate by latitude and longitude in 11 km altitude, Dec. 2002
Change of route doses 2004 – 2014
(solar cycles 23 / 24, FRA - JFK, FRA - JHB, Epcard Net 5.4.3)

Δ = 28 μSv (56 %)

Δ = 3 μSv (12 %)
Radiation exposed workers
Monitored workers and collective doses in Germany, 2012

Radiation exposed workers in Germany (2012): ca. 400,000

Collective dose of radiation exposed workers in Germany (2012): 106 pers.-Sv
Mean annual dose in work sectors
Monitored persons with measurable doses, Germany 2004 - 2012

2009, solar minimum between 23. and 24. solar cycle
Monthly doses of aircraft crews
Germany, Dec. 2003 – June 2013
Frequency distribution of doses
German aircraft personnel, 2004 – 2009 - 2014

Flight attendants

2004
2009
2012

Pilots

2004
2009
2012
### Typology of air crew members
Female flight attendants by age and dose, Germany, 2004

<table>
<thead>
<tr>
<th>Alter / Dosis [mSv]</th>
<th>0.1 - 0.5</th>
<th>0.6 - 1.0</th>
<th>1.1 - 1.5</th>
<th>1.6 - 2.0</th>
<th>2.1 - 2.5</th>
<th>2.6 - 3.0</th>
<th>3.1 - 3.5</th>
<th>&gt; 3.5</th>
<th>Summe</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 25</td>
<td>275</td>
<td>175</td>
<td>331</td>
<td>248</td>
<td>360</td>
<td>322</td>
<td>180</td>
<td><strong>286</strong></td>
<td>2.177</td>
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<tr>
<td>26 - 30</td>
<td>227</td>
<td>308</td>
<td>547</td>
<td>452</td>
<td><strong>804</strong></td>
<td><strong>722</strong></td>
<td><strong>398</strong></td>
<td><strong>244</strong></td>
<td>3.702</td>
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<tr>
<td>31 - 35</td>
<td>261</td>
<td><strong>417</strong></td>
<td>576</td>
<td>424</td>
<td>640</td>
<td>606</td>
<td>259</td>
<td>85</td>
<td>3.268</td>
</tr>
<tr>
<td>36 - 40</td>
<td>261</td>
<td><strong>474</strong></td>
<td><strong>875</strong></td>
<td><strong>641</strong></td>
<td>711</td>
<td>509</td>
<td>227</td>
<td>28</td>
<td>3.726</td>
</tr>
<tr>
<td>41 - 45</td>
<td>85</td>
<td>211</td>
<td><strong>570</strong></td>
<td><strong>453</strong></td>
<td>404</td>
<td>324</td>
<td>97</td>
<td>8</td>
<td>2.152</td>
</tr>
<tr>
<td>&gt; 45</td>
<td>47</td>
<td>111</td>
<td>255</td>
<td><strong>263</strong></td>
<td>299</td>
<td><strong>306</strong></td>
<td>122</td>
<td>9</td>
<td>1.412</td>
</tr>
<tr>
<td>Summe</td>
<td>1.156</td>
<td>1.696</td>
<td>3.154</td>
<td>2.481</td>
<td>3.218</td>
<td>2.789</td>
<td>1.283</td>
<td>660</td>
<td>16.437</td>
</tr>
</tbody>
</table>

Holm-Bonferroni test at multiple α–level: \( p < 0.05, 0.01, 0.001 \)
### RP problems in aviation

<table>
<thead>
<tr>
<th>Protection principle</th>
<th>Application to aviation</th>
<th>Practical consequences</th>
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</thead>
<tbody>
<tr>
<td><strong>Distance</strong></td>
<td>lower cruising altitude</td>
<td>- more fuel consumption, - higher cost, - more environmental burden.</td>
</tr>
<tr>
<td><strong>Shielding</strong></td>
<td>at fuselage protective clothes, cruising along lower latitudes</td>
<td>- not feasible (weight), ineffective (energy), - ineffective, not acceptable, - not applicable, - ineffective: longer routes → more radiation exposure, - (see above).</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>less block hours</td>
<td>- more part time personnel, - economically not acceptable</td>
</tr>
</tbody>
</table>
Optimization by work planning

- Allocation of personnel to route-mix

- Multi-type employment of pilots: long-haul / short-haul mix within aircraft families

Problems: Goal conflicts (flight attendants), costs
Optimization by flight planning

Calculation programs for cost-optimized flight routes:

Optimization criteria:
Fuel consumption, flight time \(+ route dose\)

\textit{Problem:} costs
Optimization en route
RP policy of IFALPA*

- Avoid flying above optimum flight level
- Avoid last step climb
- Avoid intermediate step climbs with following descent
- Cruise at lower flight level with true air speed of originally planned higher flight level (at least for the later part of flights)
- Act on ambient dose rate (on board dosemeter)

*) International Federation of Air Line Pilots' Associations
Global airspace at 12:00 GMT
Going global - via North Pole

Traffic Density for Northern Cross-polar Routes 2000-2010

© FAA Examination of Space Weather in Support of Aviation, AMS 7th Symposium on SWx, January 2010
Future challenges

• Development of new ultra-long-range aircraft
  (> 15,000 km, altitude 43,000 ft.)

• Longer non-stop flights
  (> 15 h, e.g. Singapore – New York)

• Increase of long-haul route doses: by 30 - 50 %
  (estimation by VC Cockpit, Germany)
How to manage?

- RP in aviation on international level

- Co-operation with national and international stakeholders, in particular pilot organisations

- Seek for synergy effects between radiation protection, flight safety and airline business needs.
Thank you!

Quelle: http://www.lens-flare.de/flugzeug-zwischen-wolken-5655.htm