U.S. Radiation Dose Limits for Astronauts

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Daniel J. Strom, Ph.D., CHP

Pacific Northwest National Laboratory
Strom@PNNL.gov
+1 509 375 2626

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NCRP Reports on Space Radiation

- National Council on Radiation Protection and Measurements (NCRP). Guidance on Radiation Received in Space Activities. Report No. 98. 1989.
- Radiation Protection Guidance for Activities in Low Earth Orbit. NCRP Report No. 132. 2001.
- Fluence-Based and Microdosimetric Event-Based Methods for Radiation Protection in Space. NCRP Report No. 137. 2001.
- Information Needed to Make Radiation Protection Recommendations for Space Missions Beyond Low-Earth Orbit. NCRP Report No. 153. 2006.

Space Travel

- In LEO, one is within the earth's protective magnetosphere, which deflects most of the solar wind from our sun
- Space travel above LEO results in exposure to the solar wind, which consists mostly of protons

NCRP 132: Deterministic Effects

$$\text{Gy} - \text{Eq} = \sum_{R} RBE_{R} \sum_{T} w_{T} D_{T,R}$$

Gray-Equivalent Limits (Gy-Eq)			
	BFO	**Eye**	**Skin**
Career	**Stochastic**	**4.0**	**6.0**
1 year	**0.50**	**2.0**	**3.0**
30 day	**0.25**	**1.0**	**1.5**

NCRP 132: Stochastic Effects

- 3% increase in cancer deaths

$$E = \sum_R w_R \sum_T w_T D_{T,R}$$

Career Effective Dose Limits (Sv)				
Age at Exposure	**25**	**35**	**45**	**55**
Male	**0.7**	**1.0**	**1.5**	**3.0**
Female	**0.4**	**0.6**	**0.9**	**1.7**

Van Allen Belts - 1

- Radiation belts
  - regions of high-energy particles
  - mainly protons and electrons
  - held captive by the magnetic field of the Earth
- 2 main sources
  - small but very intense inner belt (“the Van Allen Belt" discovered in 1958 by James Van Allen) is trapped within 6500 km of Earth's surface. It consists mainly a high-energy protons (10-50 MeV) and is a by-product of the cosmic radiation, a thin drizzle of very fast protons and nuclei which fill our galaxy
- http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970228a.html

Van Allen Belts - 2

- There exist electrons and protons (and also oxygen atoms) given moderate energies (1-100 keV) by processes inside the domain of the Earth's magnetic field
- Some electrons produce the polar aurora ("northern lights") when they hit the upper atmosphere, but many get trapped, and among those, protons and positive particles have most of the energy

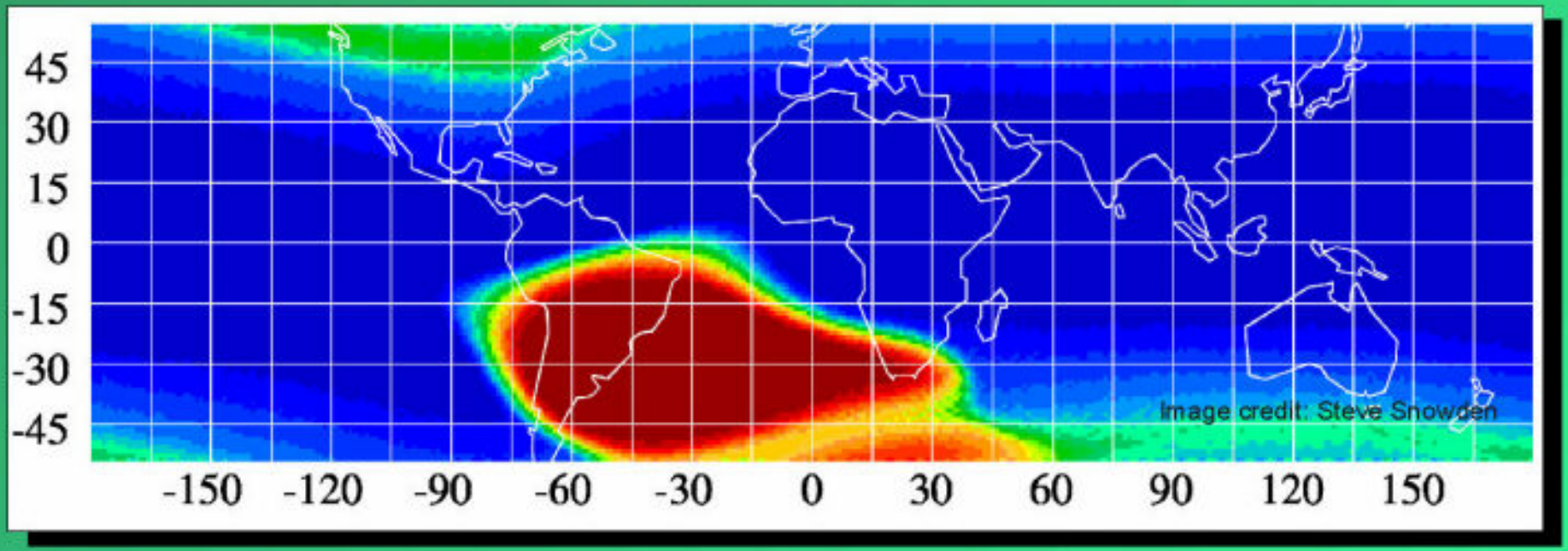
Van Allen Belts - 3

- A typical satellite passing the radiation belts (elliptic orbit, 200 miles to 20000 miles) receives about 2500 rem/year, assuming 1 g/cm^2 of aluminum (about 1/8" thick plate) almost all of it while passing the inner belt.
- The way the particles move in the magnetic field prevents them from hitting the atmosphere, and even if they are scattered, the atmosphere absorbs them long before they get very far.

The South Atlantic Anomaly (SAA)

- the region where Earth's inner van Allen radiation belt makes its closest approach to the planet's surface
- for a given altitude, the radiation intensity is higher over this region than elsewhere
- produced by a "dip" in the Earth's magnetic field at that location

South Atlantic Anomaly

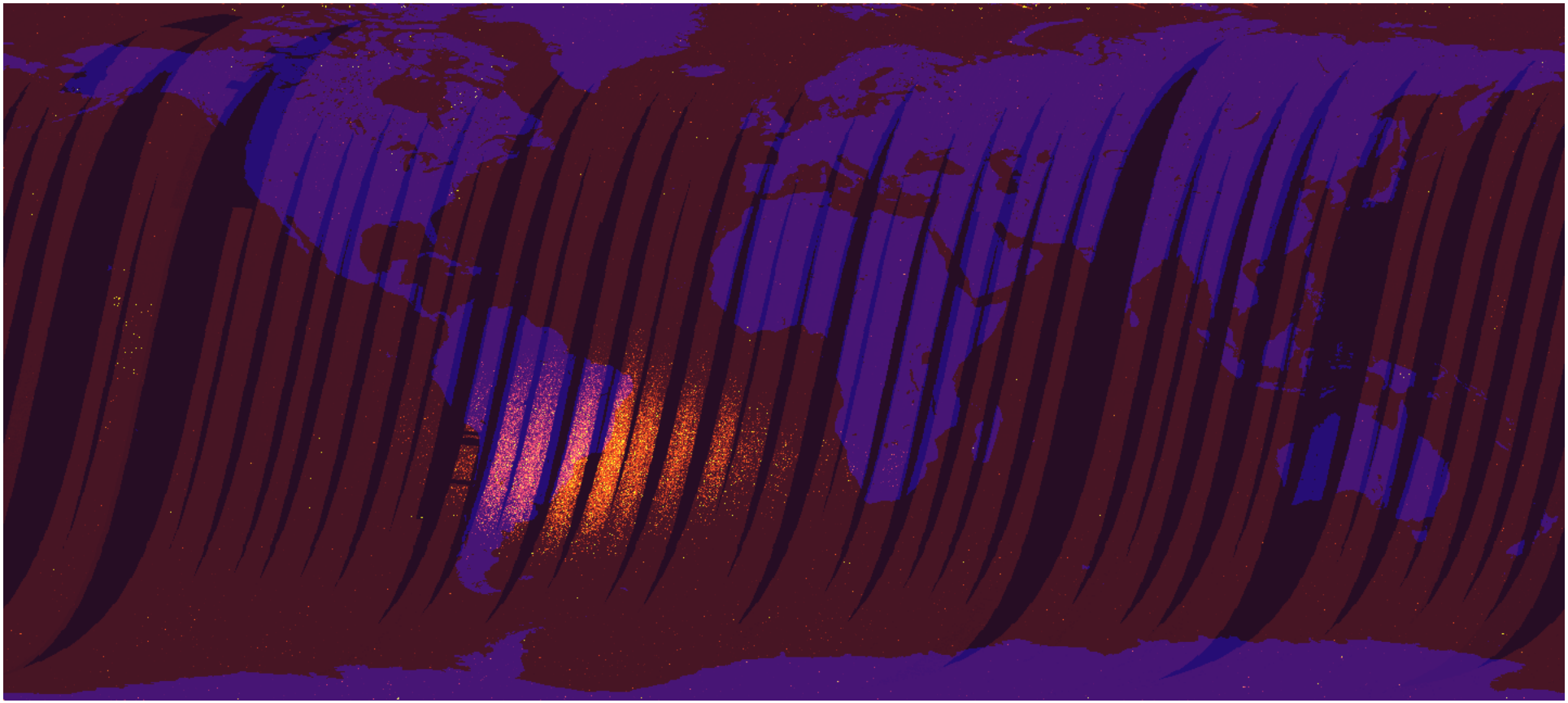


The South Atlantic Anomaly (SAA) is a dip in the Earth's magnetic field which allows cosmic rays and charged particles to reach lower into the atmosphere and interfere with communication with satellites, aircraft, and the Space Shuttle. The geologic origin is not yet known.

The enhanced particle flux in the SAA also strongly affects X-ray detectors, which are in essence particle detectors. The ROSAT PSPC had to be turned off during passage through the SAA to prevent severe damage. While the ROSAT HRI could be left on during the passage, it could collect no useful data. The light blue and green bands at the top and bottom of the image are due to an enhanced particle flux above Earth's auroral zones (particle belts).

http://heasarc.gsfc.nasa.gov/docs/rosat/gallery/display/saa.html

MISR Shows South Atlantic Anomaly

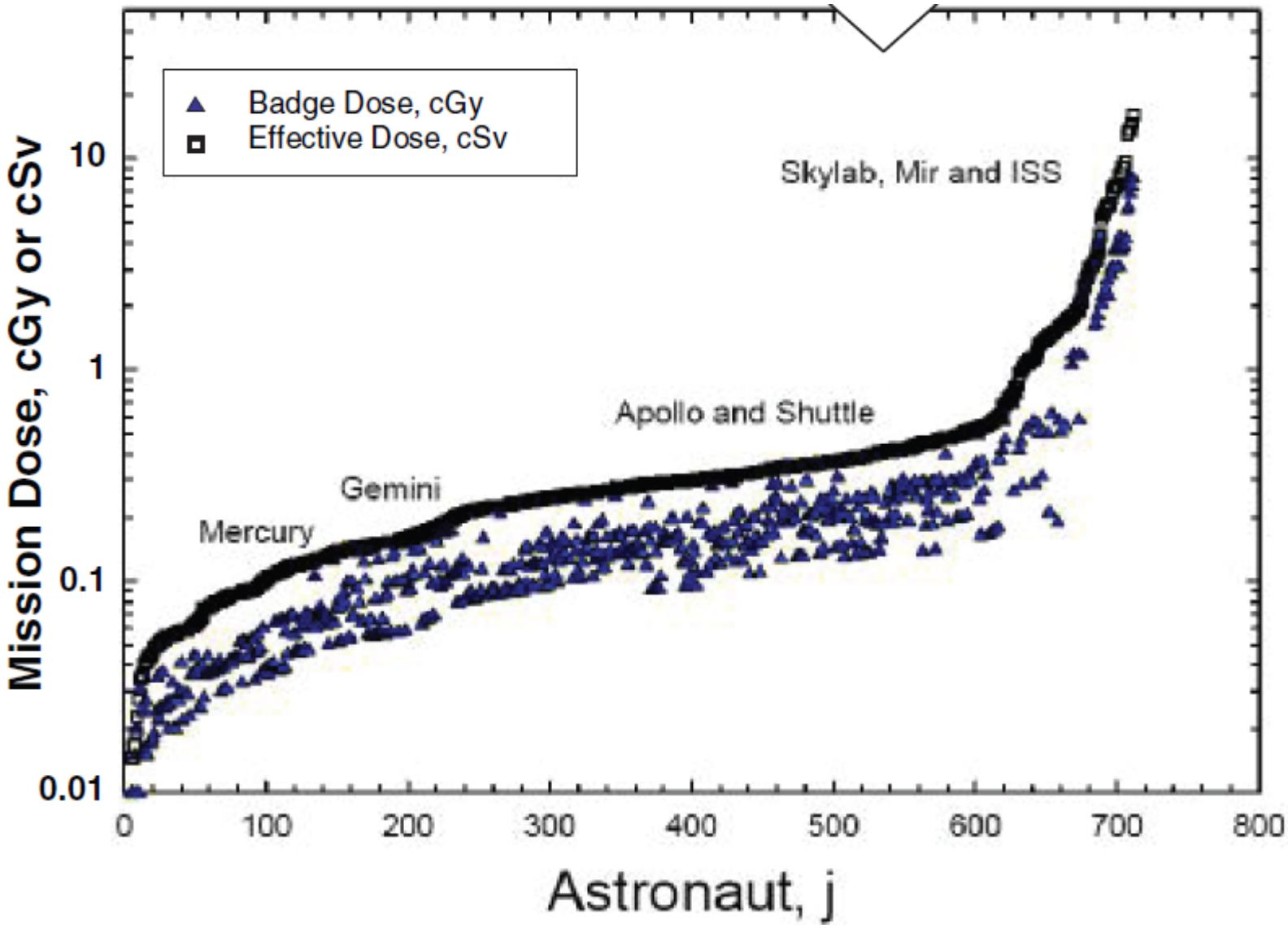


- Multi-angle Imaging SpectroRadiometer (MISR) instrument aboard NASA's Terra spacecraft began making scientific measurements. The MISR cameras, designed to detect visible light, are also sensitive to energetic protons in Earth's upper atmosphere. With the cover closed, background levels of protons stand out.
- http://eosweb.larc.nasa.gov/HPDOCS/misr/misr_html/darkmap.html

NAS-NRC 2008 Report

- Committee on the Evaluation of Radiation Shielding for Space Exploration, National Research Council. *Managing Space Radiation Risk in the New Era of Space Exploration.* Washington, DC:National Academy Press. http://www.nap.edu/catalog/12045.html

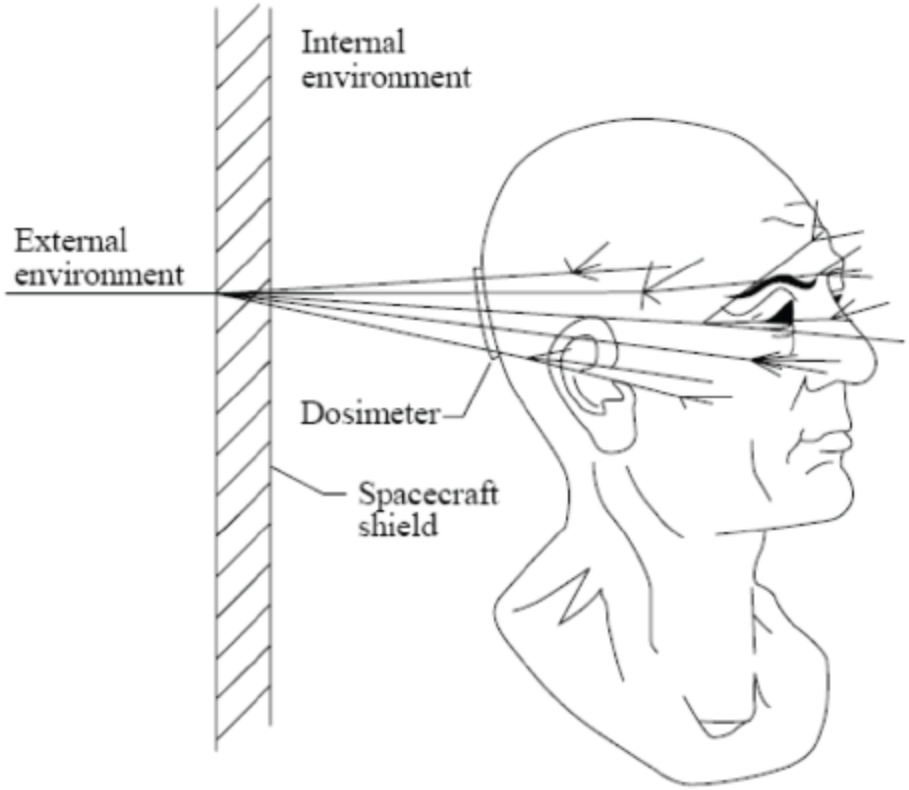
Historical Mission Doses



Space Radiation outside of the Earth's Magnetosphere

- Solar wind
- Solar Particle Events (SPEs)
- Galactic cosmic radiation (GCR)
  - Mostly protons
  - There is some high-*Z*, high-*E* (HZE) radiation

Space Radiation Protection Problem (Wilson et al. 1997)



NASA

- Sharpening their pencil on RBEs
- Expressing everything probabilistically
- Changing "excess lifetime risk“ (ELR) 3% to
  - "risk of exposure-induced death" (REID) 3%
- Adding 95% confidence intervals (CI) for uncertainty

NAS-NRC REID Calculation

3% REID				
	Males		Females	
Age	*E*(cSv)	Days	*E*(cSv)	Days
30	62	142	47	112
35	72	166	55	132
40	80	186	62	150
45	95	224	75	182
50	115	273	92	224
55	147	340	112	282

REID: Radiation-induced excess death

cSv: centisieverts

REID on a Mars Mission

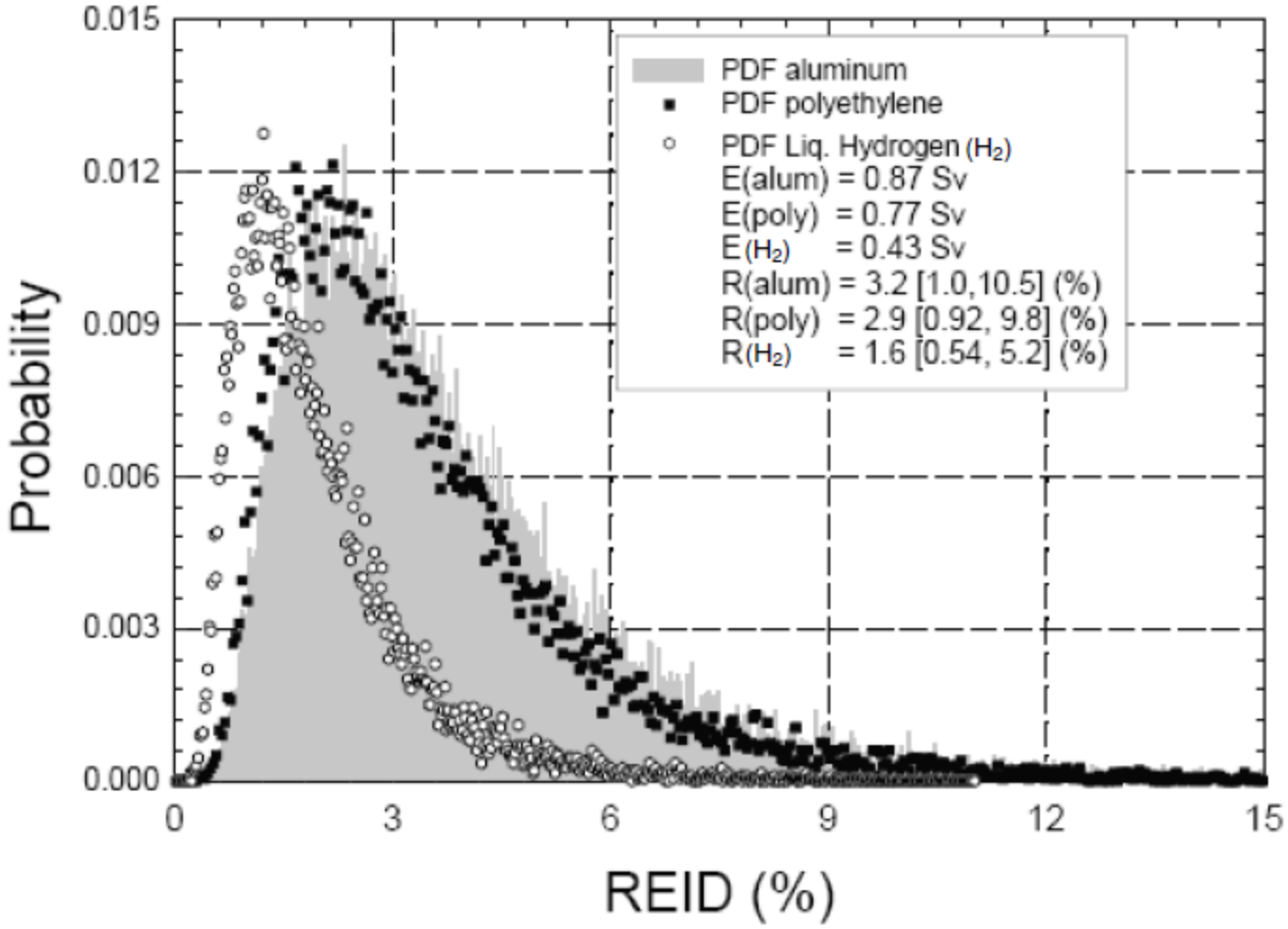


FIGURE 3-4 Probability density functions (PDFs) for 40-year-old males on a solar minimum Mars swing-by mission behind 20-g/cm^2 shields of aluminum, polyethylene, or liquid hydrogen. Effective doses, point estimates, and 95 percent confidence interval for risk of exposure-induced death (REID) are shown in the inset. SOURCE: Cucinotta et al., 2005.

Conclusions

- Risk depends on age and sex
- Limits based on age and sex conflict with Equal Employment Opportunity law
  - not used here on earth