

COSMIC RADIATION IN AVIATION

The radiological protection of Air France aircraft crews

Gérard DESMARIS
Medical doctor

Air France, Occupational health service IO.ZM
45 rue de Paris,
F 93747 Roissy Charles de Gaulle Cedex, France
desmaris.g@orange.fr

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HISTORICAL ACCOUNT

DISCOVERY

V. HESS, W. KOLHORSTER 1912-1913

A. MILLIKIAN 1925

P. AUGER 1930

CONCERNS FOR MANED SPACE FLIGHT

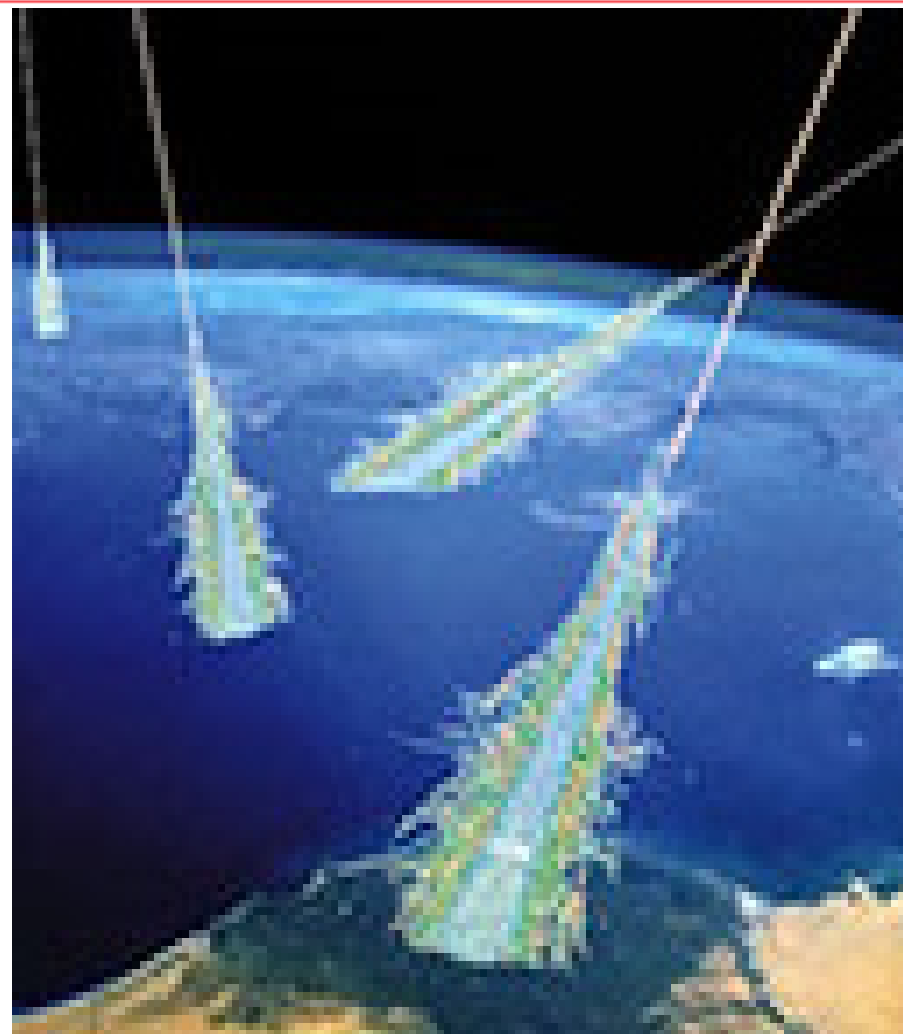
D. SIMONS 1957

Man High Project

MEASUREMENTS IN SPACE

Satellites Explorer, Pioneer 1953-1958

Elektron 1964



AIR FRANCE
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HISTORICAL ACCOUNT

MEASUREMENTS ON BOARD CIVIL AIRCRAFTS

SUPERSONIC CONCORDE

Mach 2 cruise 15-18 km
1969 on board first prototype
1976 on commercial flights
Air France British Airways

SUBSONIC AIRCRAFTS

Extensive campaigns
since 1990
0,8 Mach cruise 8-12 km

RESULTS

Concorde 12-15 μSv per hour
Long haul 4-6 μSv per hour
Short haul 1-3 μSv per hour

CONSEQUENCE

750 boarding hours $\geq 1\text{mSv/year}$



NEW INTERNATIONAL RECOMMENDATIONS



ICRP 60

1991 : Recommendations of the International Commission on Radiological Protection

Two novelties :

-To take into account natural sources of ionising radiation when occupational exposure

-To lower the limits of exposure

Public < 1mSv /year

Exposed workers < 100mSv / 5 successive years

EUROPEAN REGULATION'S CHANGEOVER



COUNCIL DIRECTIVE 96/29 EURATOM

13 May 1996 applicable May 2000

The undertakings shall take appropriate measure in particular

- ◆ To assess the exposure of crew concerned
- ◆ To take into account the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed aircrews.
- ◆ To apply article 10 to female aircrew
< 1 mSv during pregnancy

THE SIEVERT SYSTEM

Système d'**I**nformation et d'**E**valuation par **V**ol de l'**E**xposition au
Rayonnement cosmique dans les **T**ransports aériens

Computerized System for Flight Assessment of Exposure
to Cosmic Radiation in Air Transport

- DGAC French Airworthiness Agency
- IRSN French Institute for Research and Nuclear Safety
- PARIS – MEUDON Observatory
- IFRTP French Institute for Research and Polar Technology
- Air France



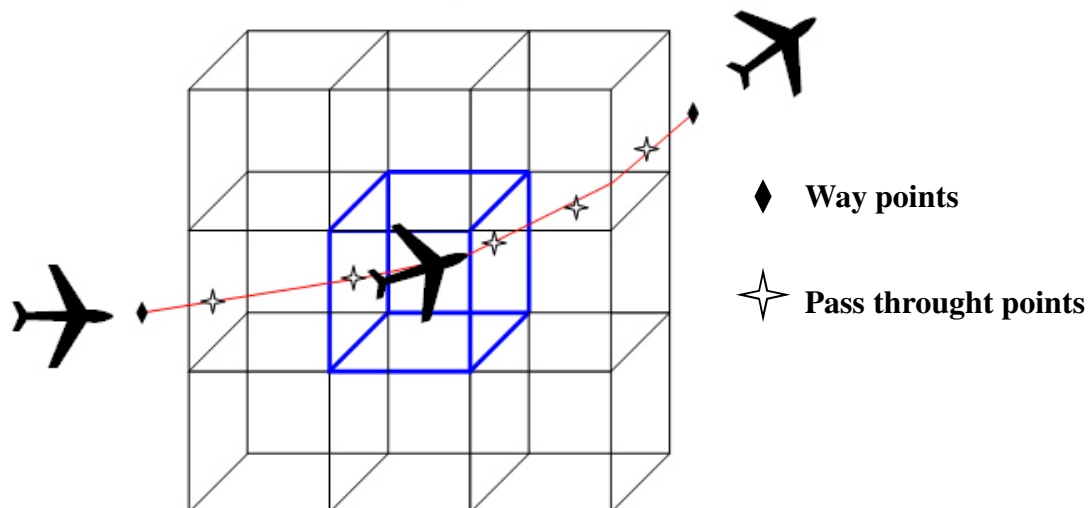
THE SIEVERT SYSTEM

3D + Time

Route with corresponding date map of dose rates

2000-2003 CARI 6 based on LUIN code

Since 2004 EPCARD 3 based on FLUKA code validated by IRSN



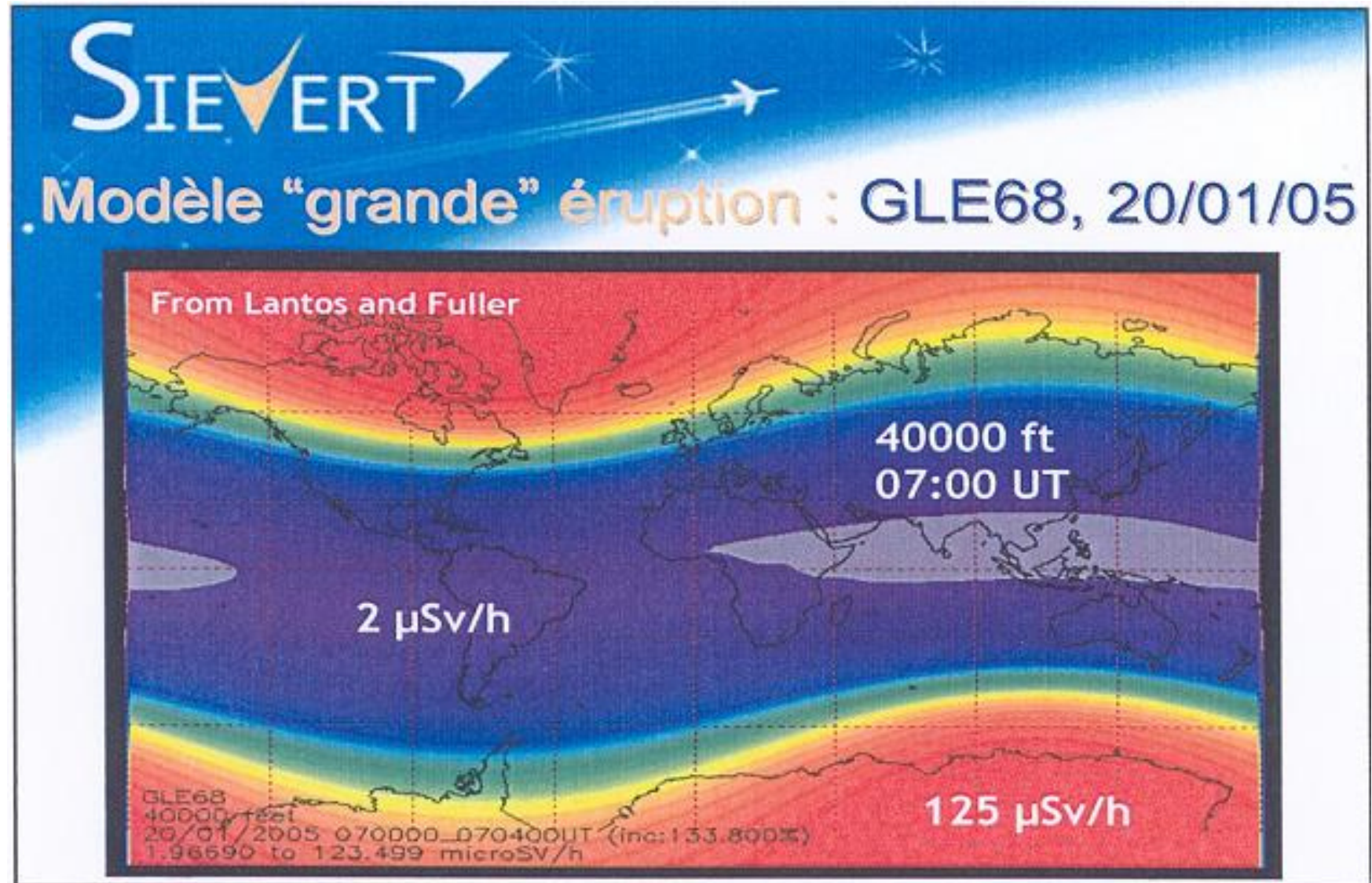
Cells altitude 1000 Feet from ground to 80 000 ft

Latitude 2°

Longitude 10°



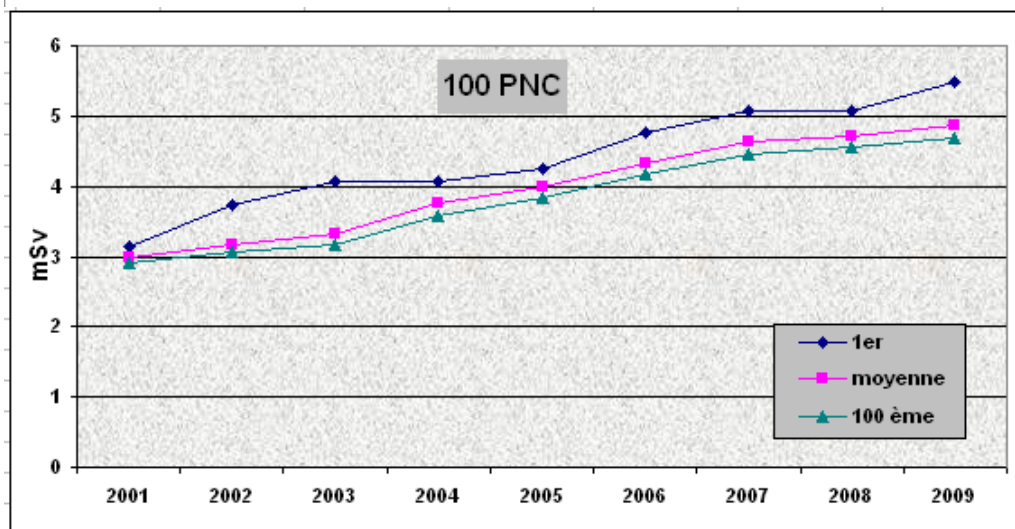
PARIS OBSERVATORY SIGLE MODEL



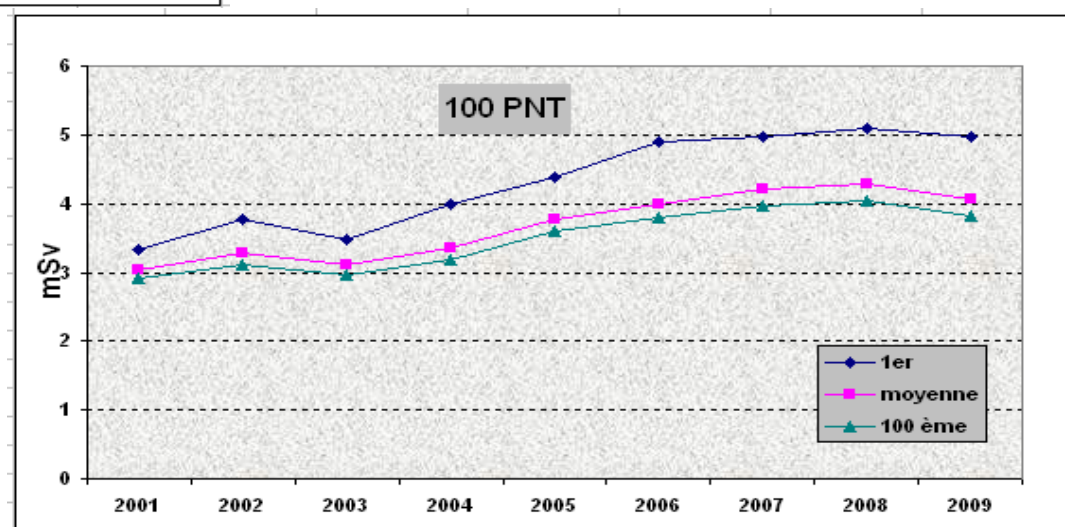
AIR FRANCE APPROACH

- Assessment of aircrew individual exposures based on the Sievert system operated by IRSN
- Specific information aircrew members
- Adjustment of the flight schedule if individual dose approaching 4 mSv/year
- Support of a radiation protection officer for scheduling flights
- Routine occupational health surveillance of flight personnel
- Pregnant female aircrew are normally suspended from flying but can exceptionally continue if they wish so

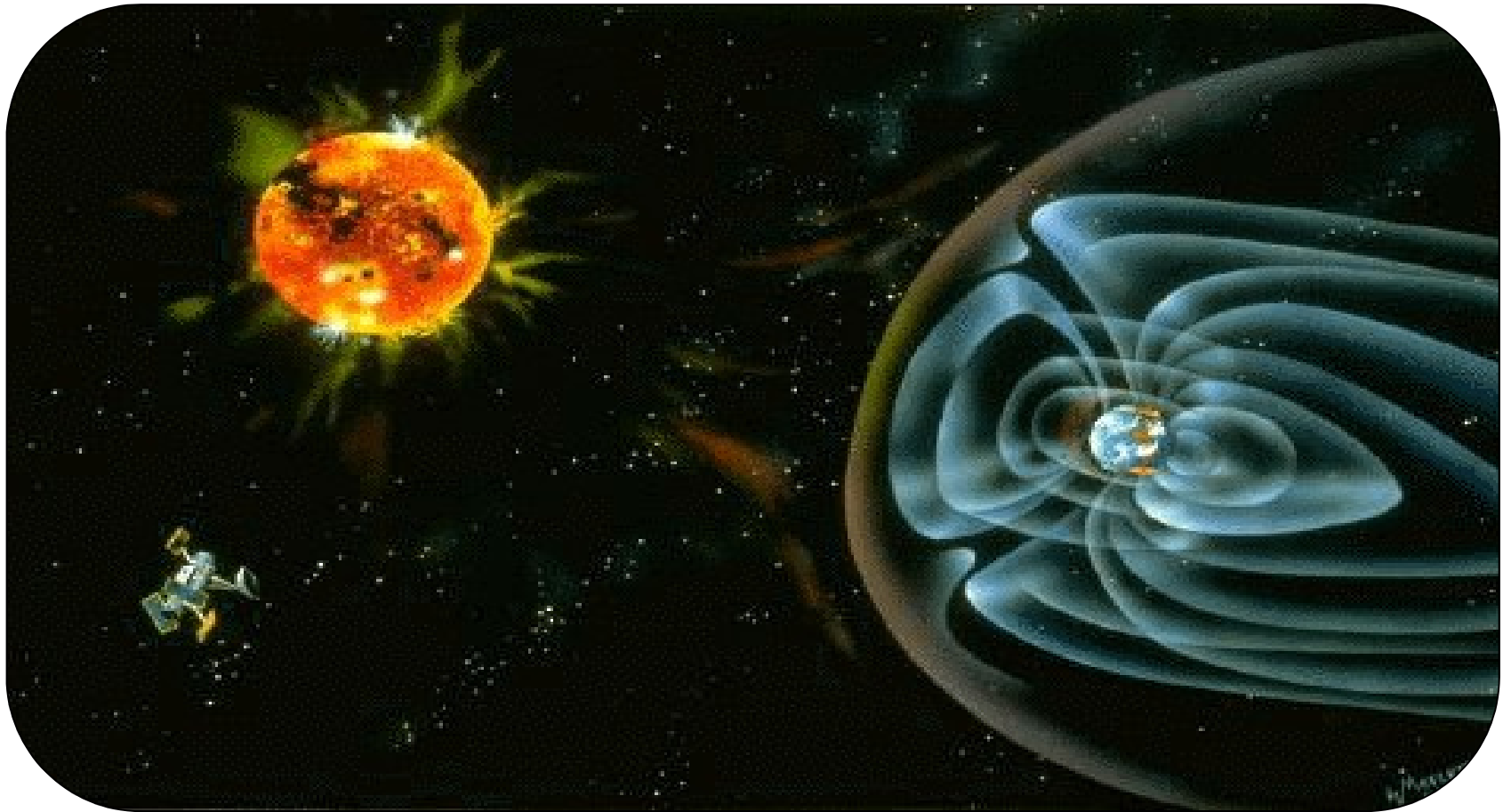
EXPOSURE'S FOLLOW UP OF AIRCREWS



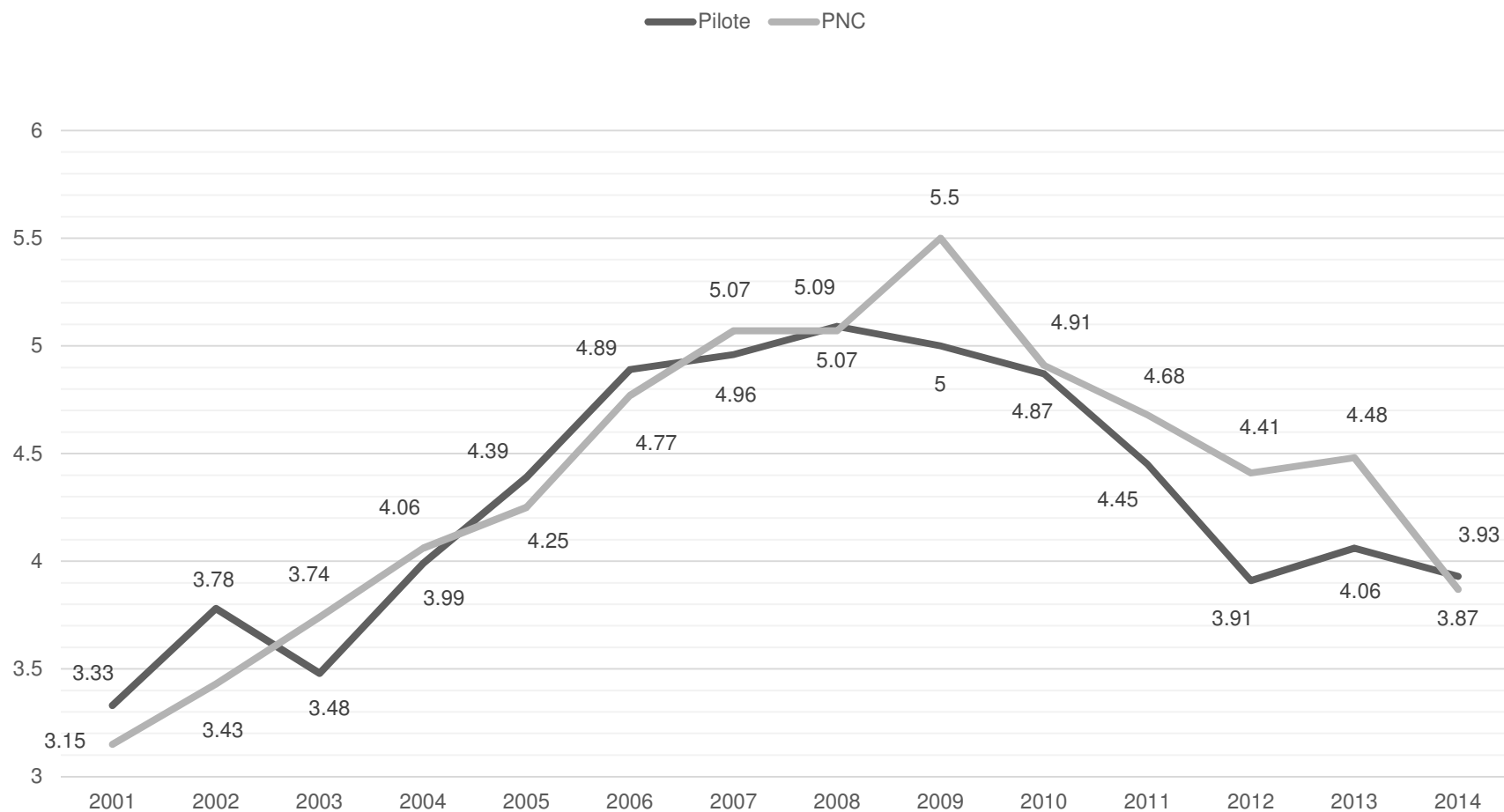
100 Flight deck crew



SOLAR WIND AND GALACTIC RAYS EARTH MAGNETIC FIELD - EARTH ATMOSPHERE

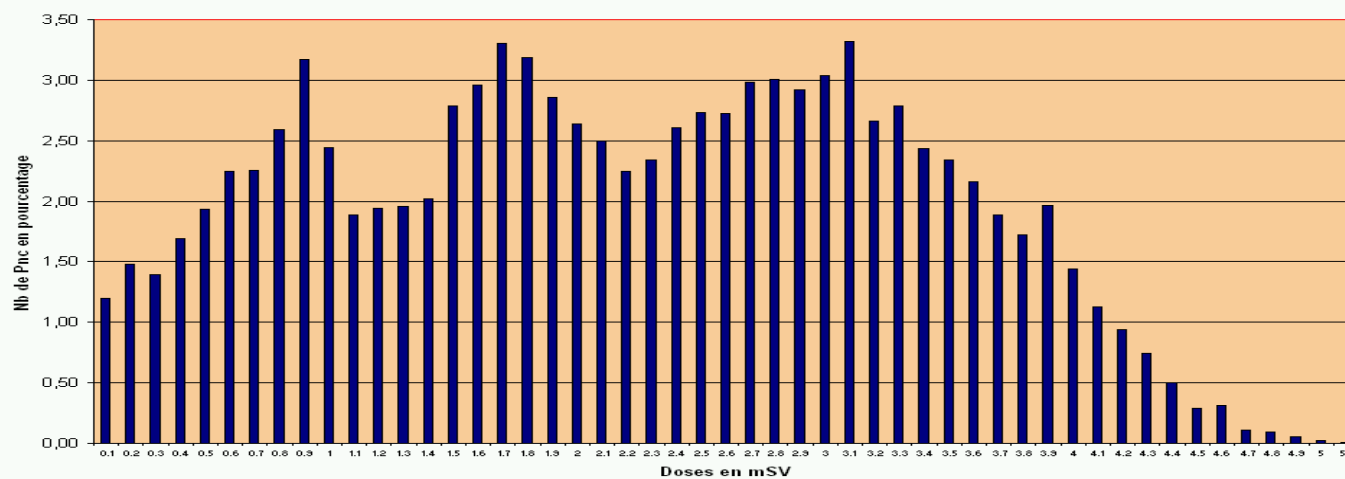


HIGHEST DOSES 2001-2014

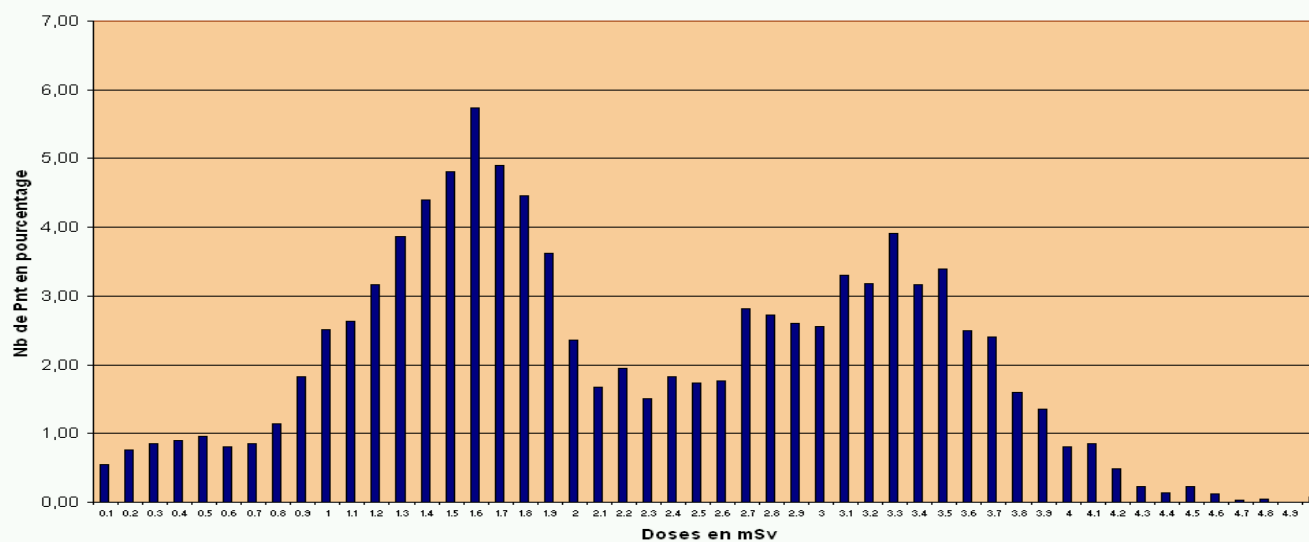


DISTRIBUTION OF INDIVIDUAL DOSES

Répartition des Doses 2008
17878 PNC

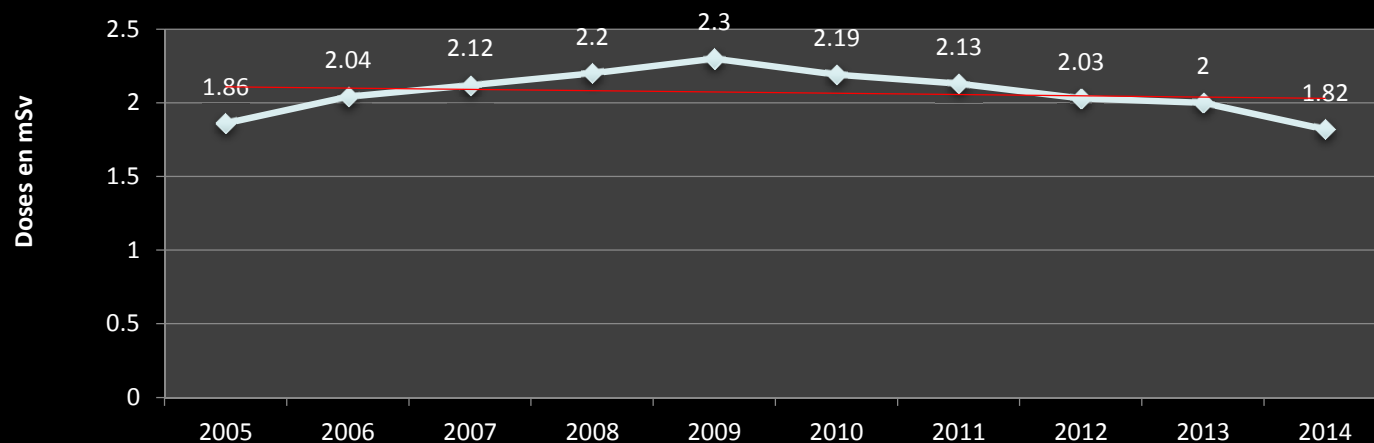


Répartition des Doses 2008
4370 PNT

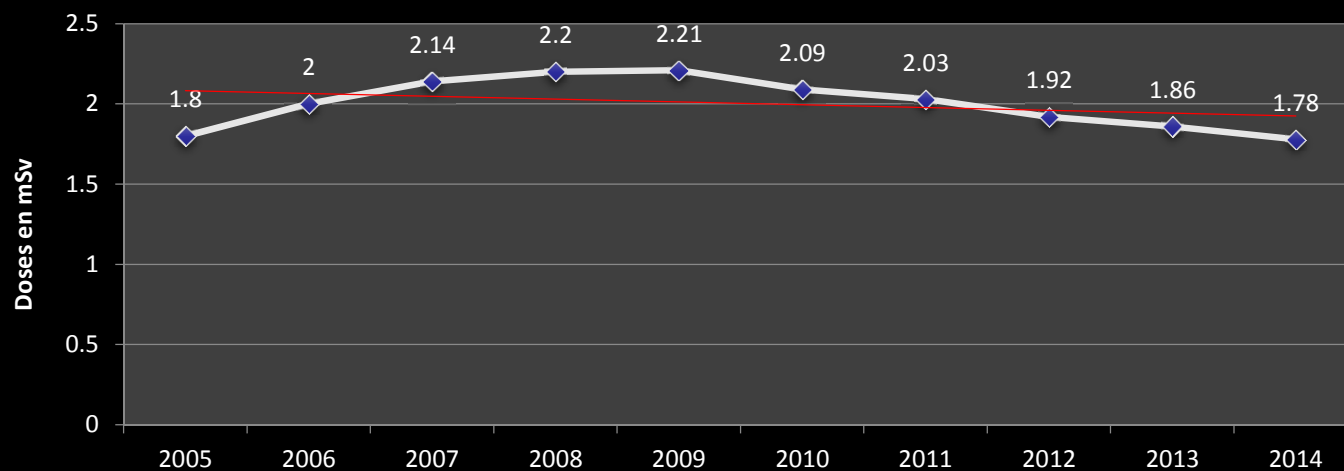


ANNUAL AVERAGE EXPOSURES 2005 - 2014

CABIN CREWS



PILOTS



PREGNANT PILOTS

Allowed to fly for the two
first trimesters since 2005
in Europe

If they agree
If they are fit

Information encourage
early report of the
pregnancy

Dose to the fetus
< 1 mSv
About 200 flying hours



TOWARD AN EDUCATIONAL PROGRAM

Operating procedure
Health manual
News bulletin
Flyers
Films
E-learning :
14,000 attendants
over 3 years



SOLAR FLARES WITH GLE

Four radiations storms taken into account since 2000

14 July 2000 GLE59

15 April 2001 GLE 60

20 January 2005 GLE 69

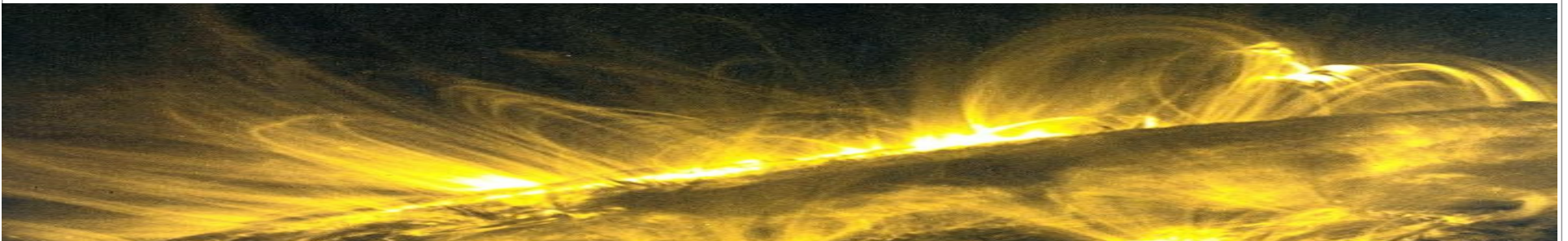
13 December 2006 GLE 70

Middle magnitude S3 :

0.1 mSv/h altitude 12 Km, duration 1 to 6 hours

Dose X 2 for flights hit

Remember GLE 05 23 February 1956 estimate 10 mSv/h



SUPERSONIC CONCORDE DURING GLE

Radiation monitoring equipment in the flight deck
Mandatory above 15 Km
Triggered at 0.5 mSv/hour

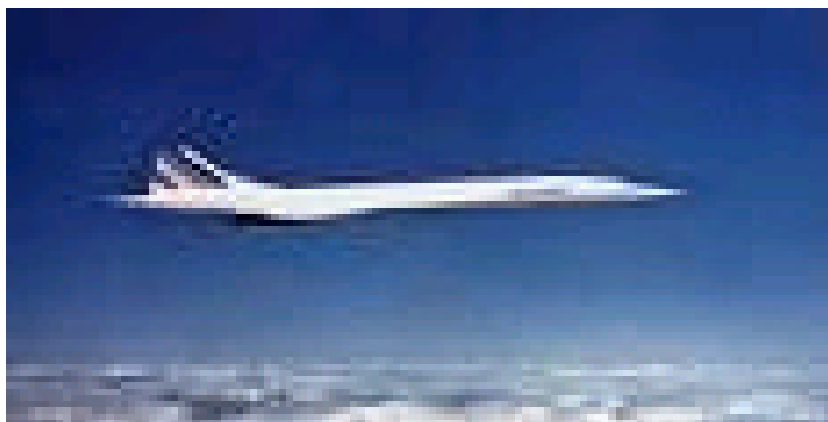
3 emergency descents reported

9 january 1997

1 mSv/h at 16 Km then 10 mSv at 17.6 Km

Return to 16 Km to pursue cruise toward NY

PARIS NEW YORK 0.5 mSv (X4)



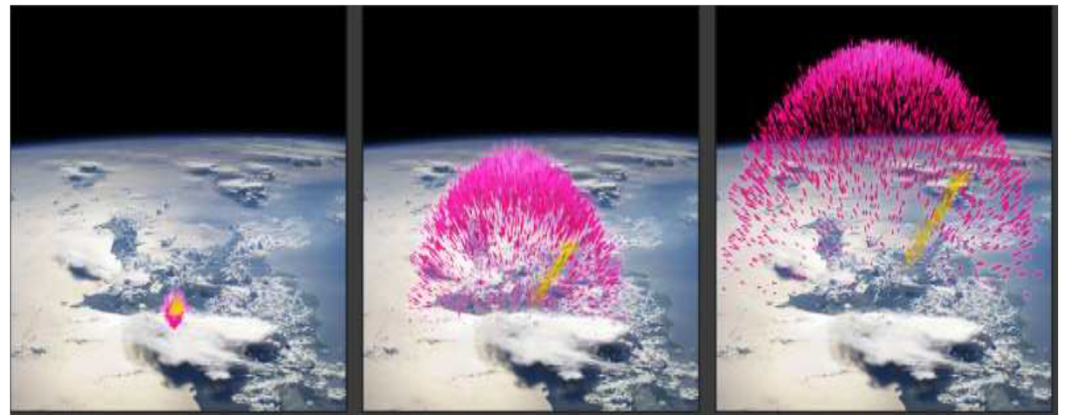
AIR FRANCE

IRSN - AF PARTNERSHIP FOR SPACE WEATHER RESEARCH

TGF

1928 RPL Dosimeters analysed
from 2009 to 2014

No trace of a TGF was found



GLE

7 Liulin and 30 EPD N2 are
today available on board
Solar Proton Event 7 January 2014
no significant dose's increase
recorded at flight level



AIR FRANCE

CONCLUDING REMARKS

Aviation is a justified activity

Although possibilities to control exposures are limited, implementation of a radiological protection strategy is feasible

The objective is :

- first to keep highly exposed crews to reasonable level
- second to raise awareness about cosmic radiation

