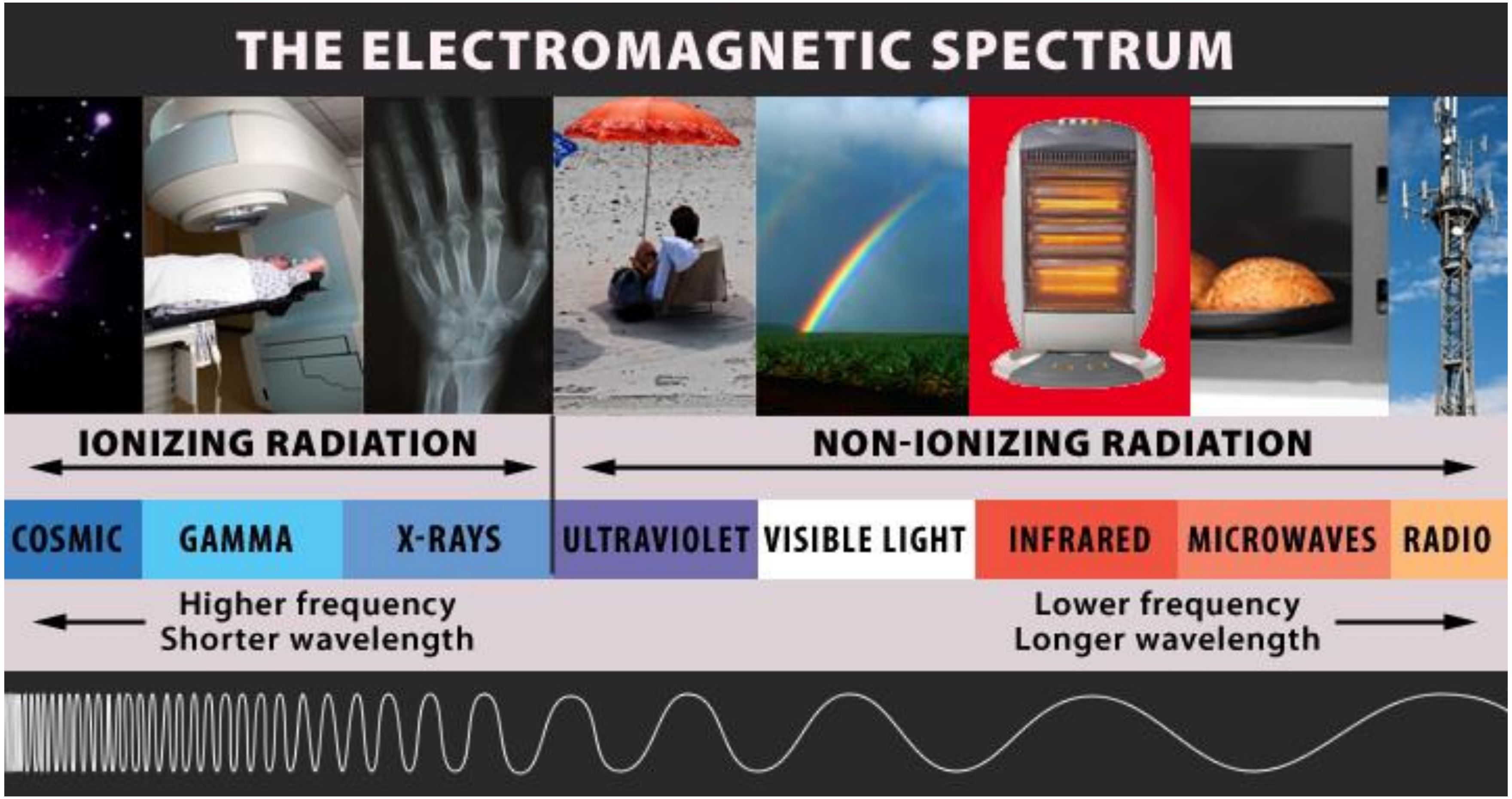
# COSMIC RADIATION

DR BERNICE MASHAPHU
SENIOR MEDICAL ASSESSOR
SACAA

# OUTLINE

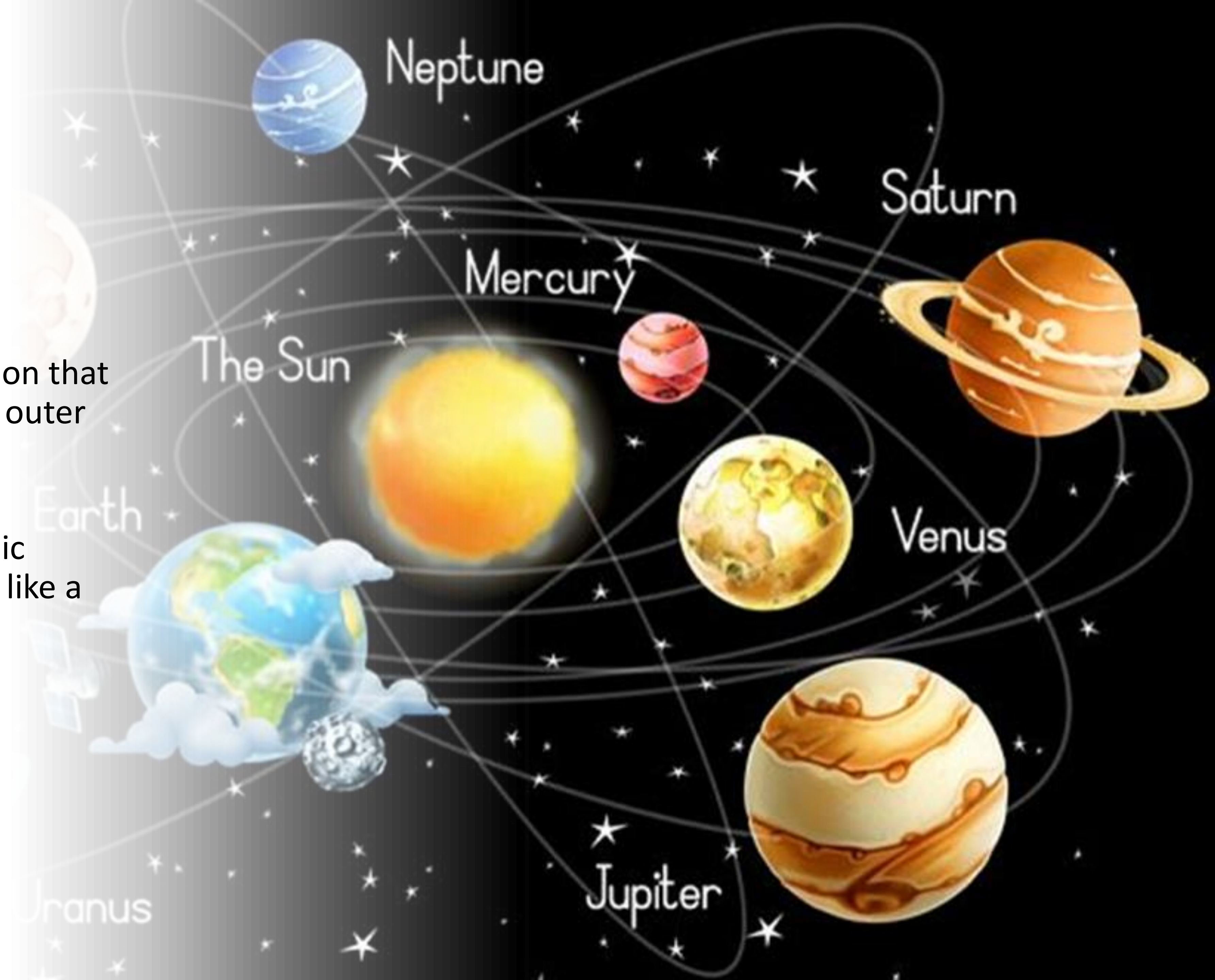
- Definition
- Applicability to Commercial aviation
- Possible effects on health of aircrews
- Epidemiology
- international best practices
- Recommendations
- Conclusion

# Radiation


THE ELECTROMAGNETIC SPECTRUM
IONIZING RADIATION
NON-IONIZING RADIATION
COSMIC
GAMMA
X-RAYS
ULTRAVIOLET
VISIBLE LIGHT
INFRARED
MICROWAVES
RADIO
Higher frequency
Shorter wavelength
Lower frequency
Longer wavelength

# COSMIC RADIATION

- A form of ionizing radiation that comes from the galaxy – outer space.
- The sun and stars send a constant stream of cosmic radiation to earth, much like a steady drizzle of rain.

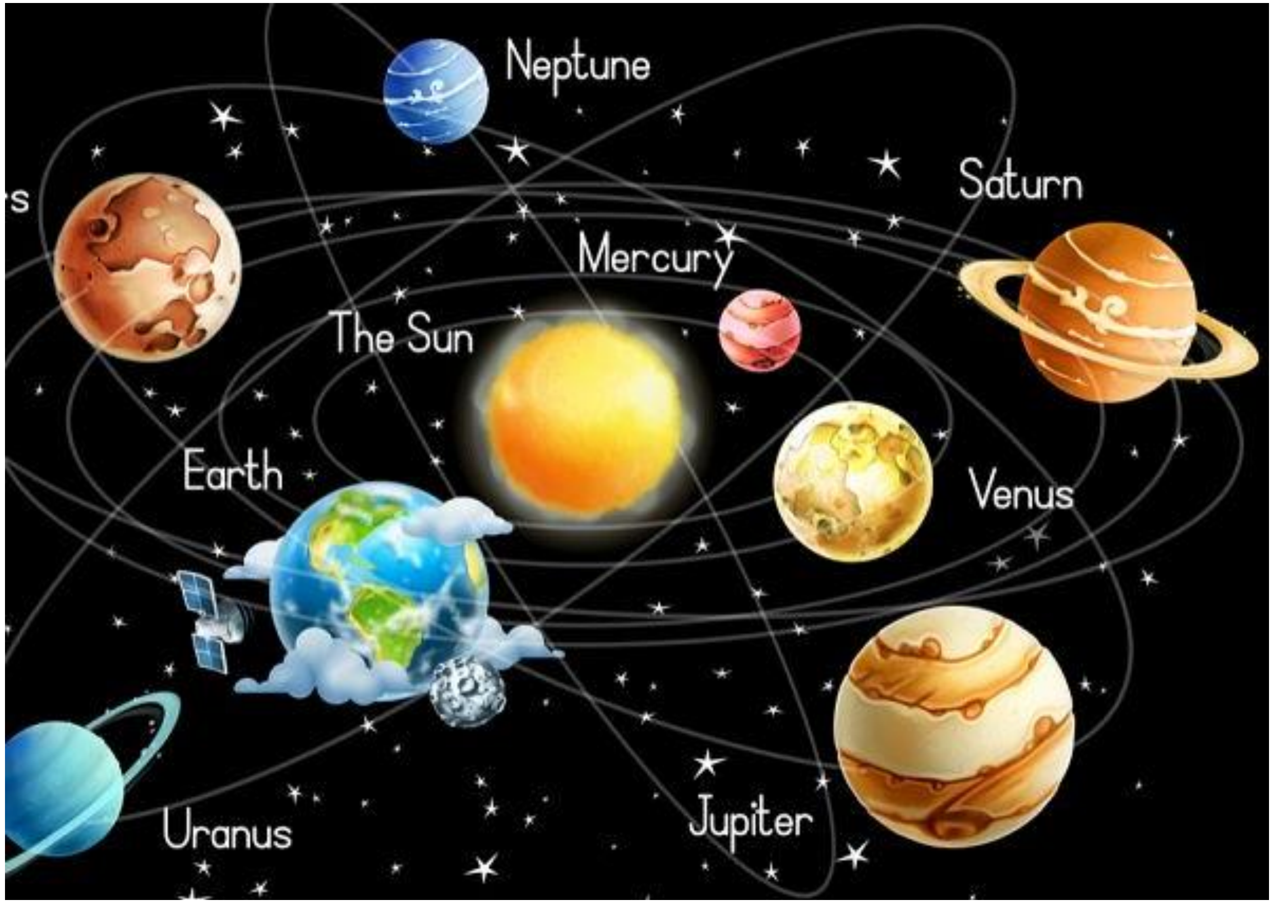


# Potential sources of CR

- Colliding galaxies
- Super-magnetized spinning neutron stars
- Giant black holes spinning rapidly
- Gamma ray bursts

# Cosmic Radiation

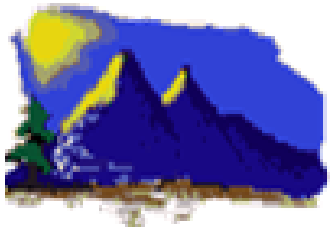
- If it originates from deep space (constant intensity), it is referred to as background CR or Galactic Cosmic Radiation (GCR),
- And if it is from the sun (intensity increases with solar flare activity), referred to as Solar Radiation.



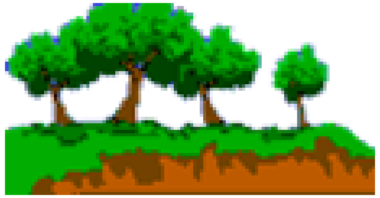
## *Naturally occurring sources*

- cosmic radiation originating in outer space and reaching the earth's surface after reacting with, and being partially absorbed by, the earth's atmosphere;

30 millirem/year

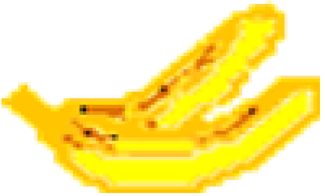


2. terrestrial radiation coming from natural radioisotopes present in the earth's crust; 30 millirem/year

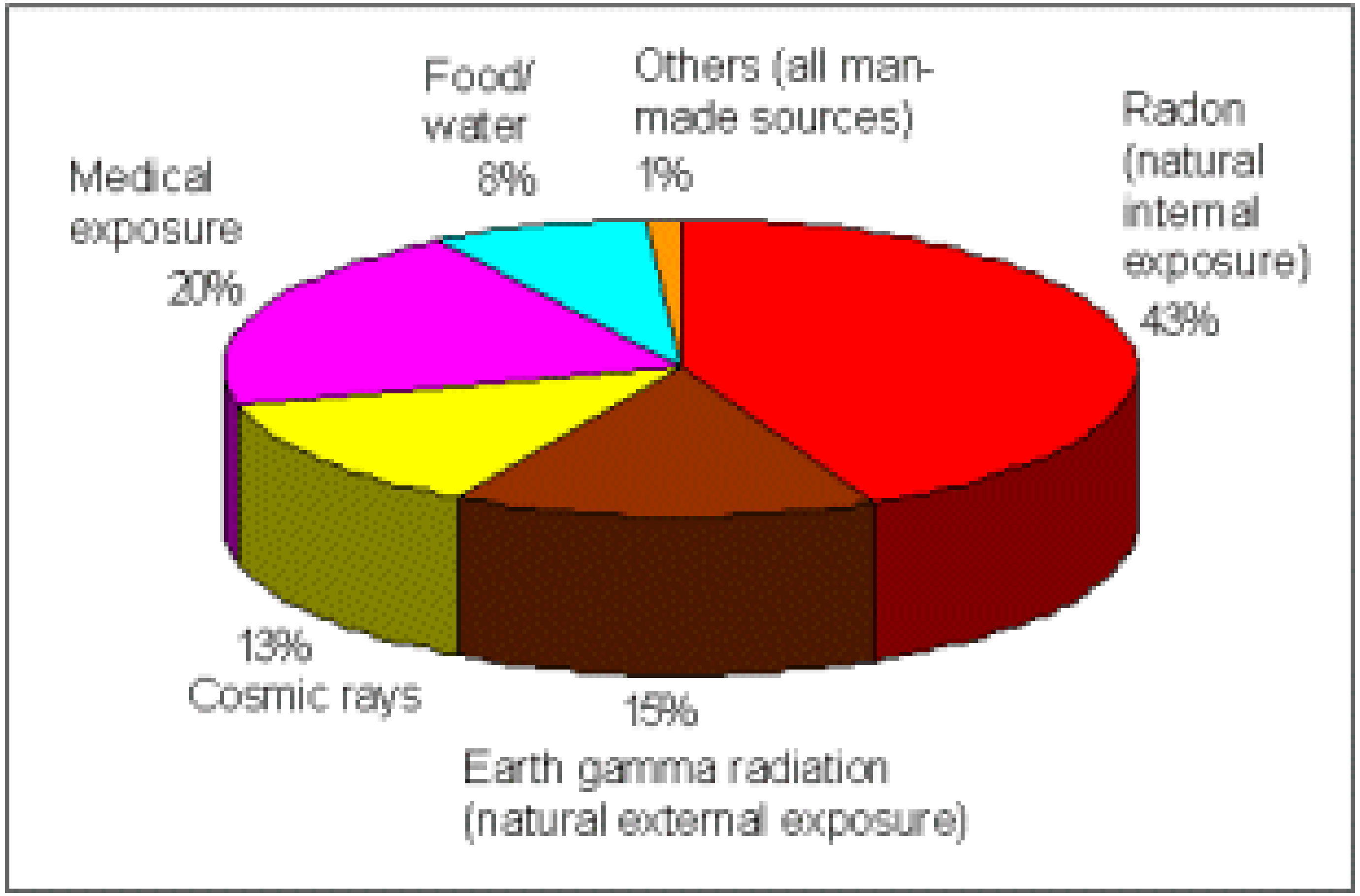


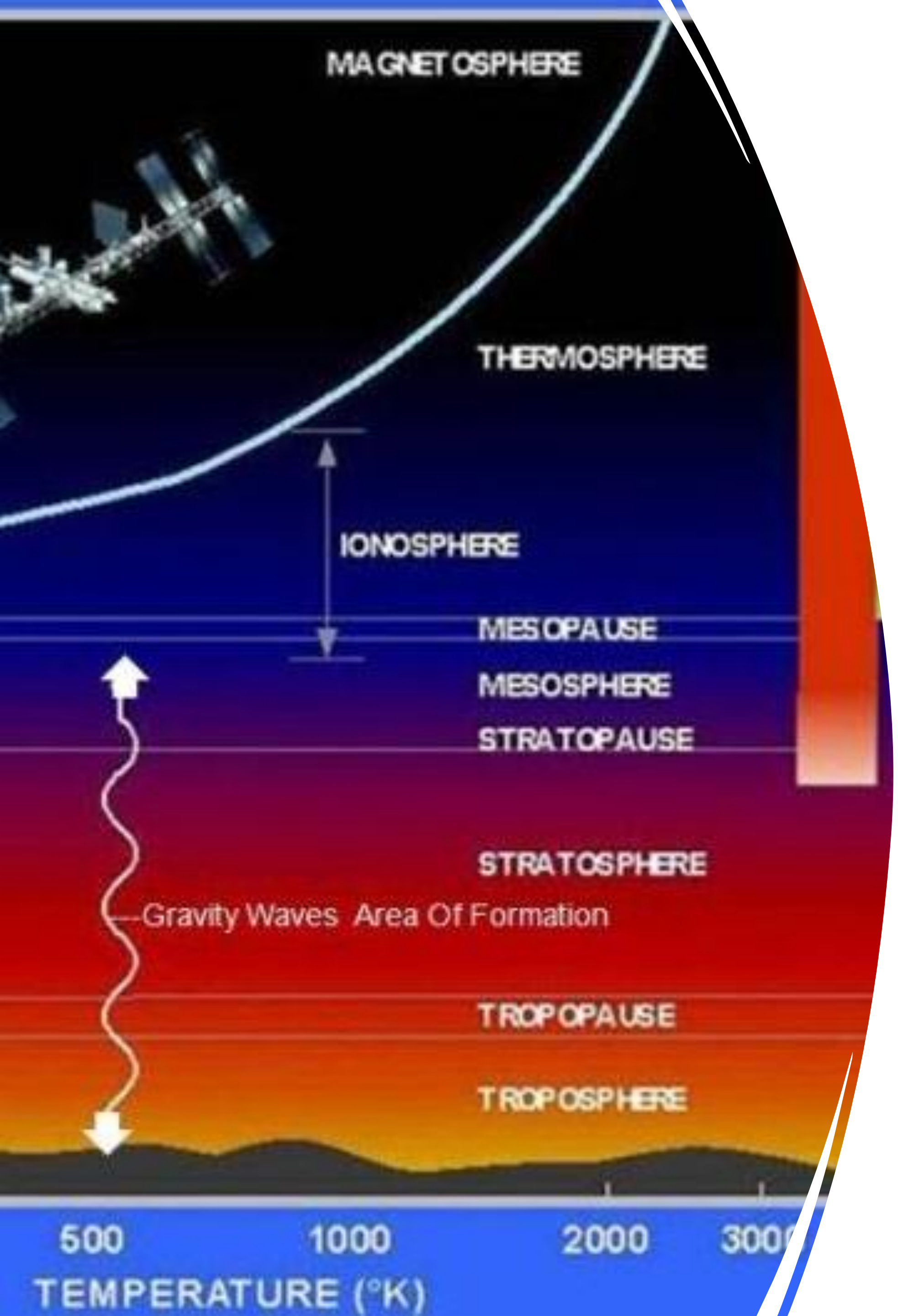
3. radiation from natural radioisotopes that have been accumulated in the body as a result of the consumption of food and water and the inhalation of air containing such radioisotopes.

40 millirem/year



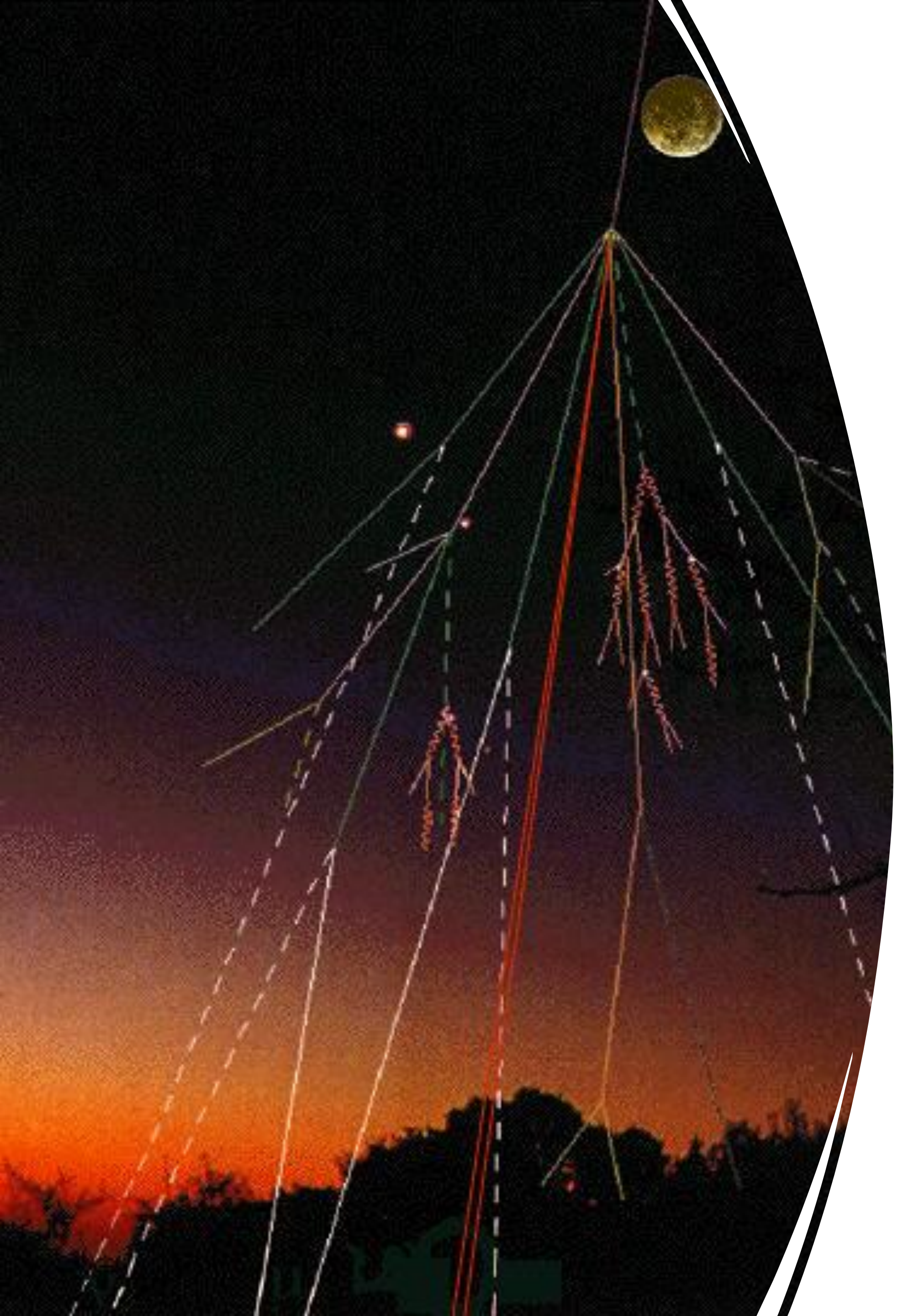
Sources & distribution of average radiation exposure to the world population






# Cosmic Radiation

- CR consists of a comprehensive spectrum of particles and electromagnetic radiation.
- Cosmic rays are radio-active particles that hit the earth from outer space and can have energies far in excess of manmade radiation sources.
- The earth's atmosphere blocks a portion of these rays, but some of them reach the ground



# COSMIC RADIATION

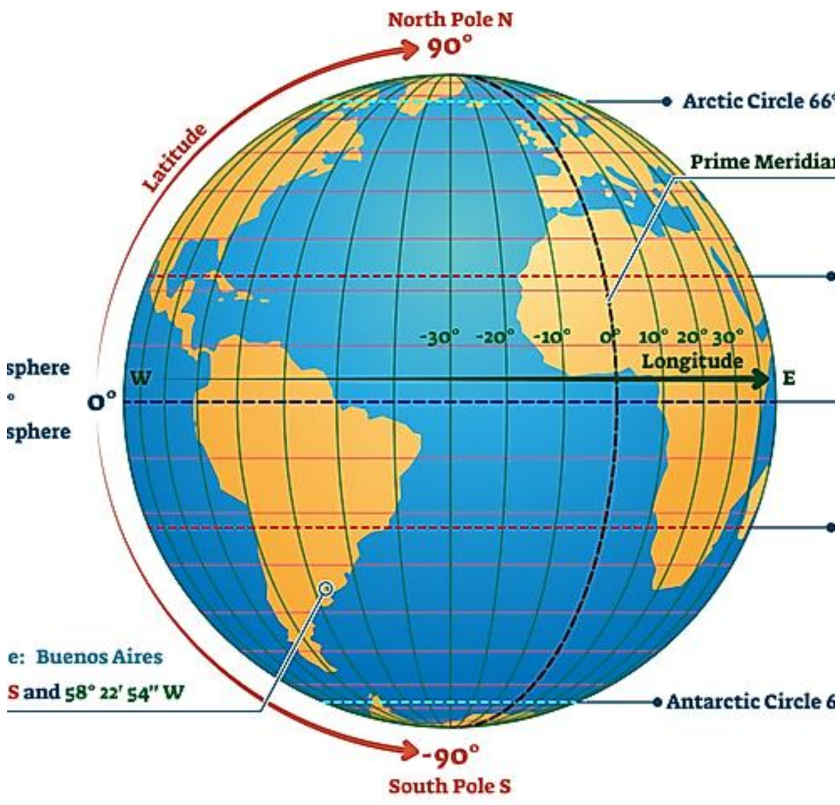
There are 3 main factors that affects the amount of exposure to cosmic radiation:

- **Altitude**: the higher we go, the greater the dose
- **Latitude:** the closer we get to the poles, the greater the dose
- **Duration:** the longer we stay aloft, the greater the dose

Effective dose rates increase with altitude up to a maximum of about 20 km (66 000 ft).

# Latitude:

- The farther north or south one is from the Equator, the more radiation one will receive.
- (this is as a result of magnetic field deflecting some of the cosmic radiation away from the equator and toward the North and South poles).
- CR increase with increasing latitude reaching a constant of about 50 degrees.



# Cosmic radiation

Therefore, the radiation dose will vary between different flights depending on:

- origin,
- destination,
- route,
- flight level pattern and
- solar activity at the time.

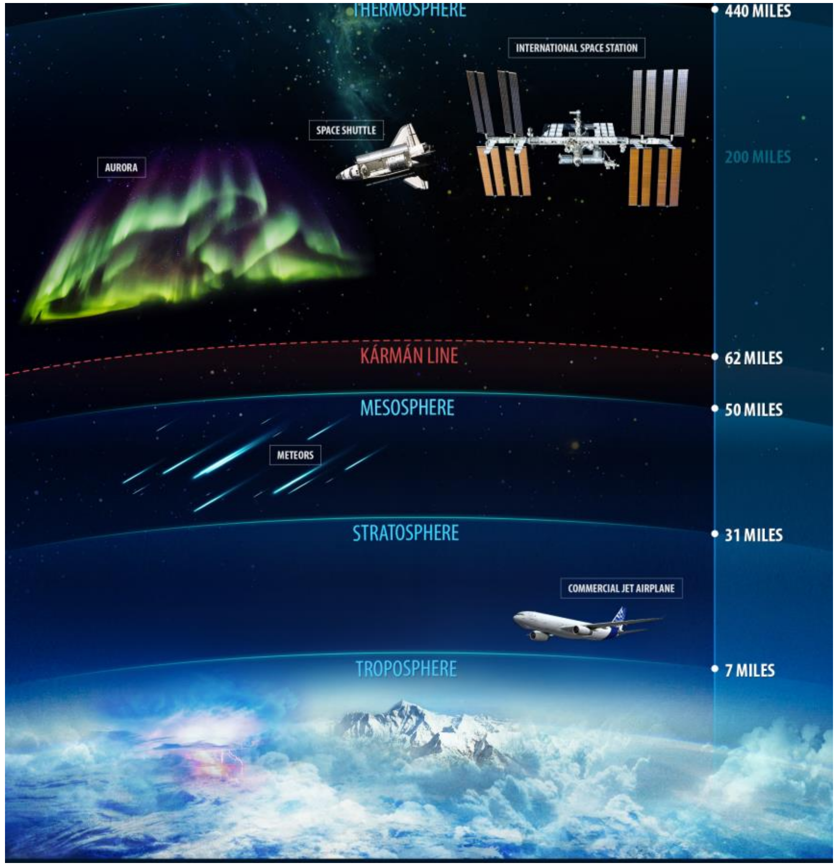
Aircrew and frequent flyers get the most additional exposure because of the extra time they spend at cruising altitudes

# Route doses

- A flight from northern Europe to the Eastern seaboard of the USA – effective dose **of 30 to 40 microSv**
- Longer flights from northern Europe to Japan will result in a dose of  **50 to 70 microSv**
- Transatlantic flights at the altitudes used by supersonic aircraft may give similar total effective doses as in subsonic aircraft, the higher dose rates being offset by the shorter flight times.

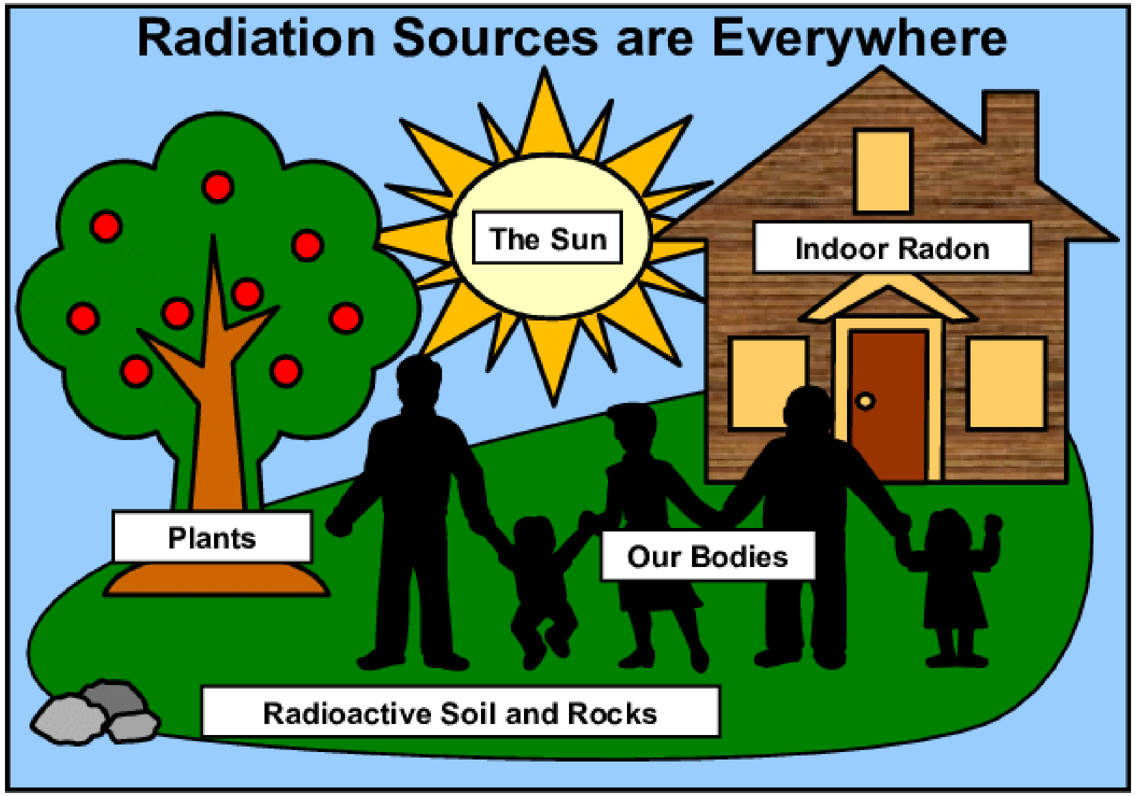
# Cosmic Radiation

- Airline pilots and flight attendants, who spend many hours at high elevations, are exposed to more of these rays.
- General public is also exposed to higher levels of cosmic rays during airplane flights.

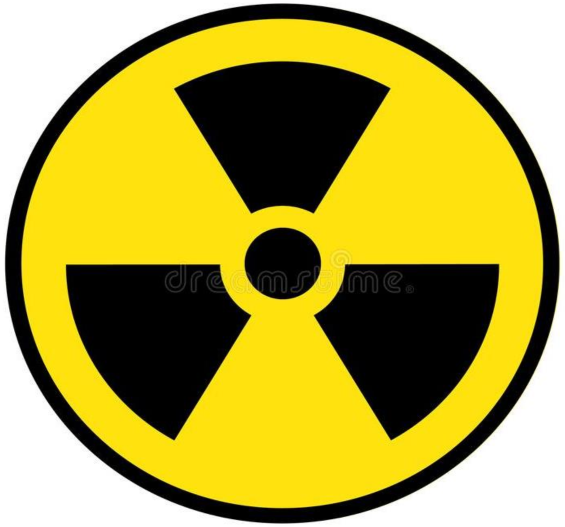


# COSMIC RADIATION

- The average annual exposure from CR is **0.33 mSv (33 rem)** or 11% of a person's yearly exposure due to all natural sources of radiation. (ordinary people on the ground)
- (this yearly amount of radiation is similar to the amount of radiation from **3 chest X-rays**.)



# Cosmic Radiation



- The consequences of irradiation of individuals are regularly reviewed by the ICRP. (Latest publication from 1991 [ICRP Publication 91])

**The main concern with CR exposure is:**

  - The possible long term risk of radiation induced cancer

*(Friedberg et al estimated that the increased risk of dying from cancer because of cosmic radiation received over 20 years of flying, ranges from 0.1 to 5 in 1000.)*

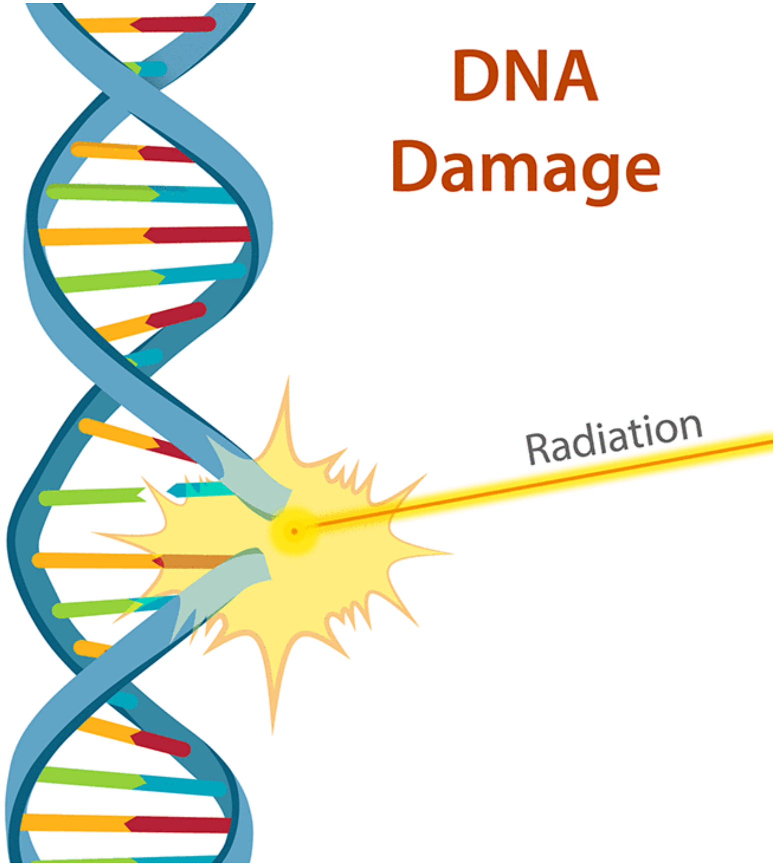
  - In the case of pregnant air crew, possible harm to the foetus – mainly ***stochastic*** effects later in life and to a lesser extent, birth defects

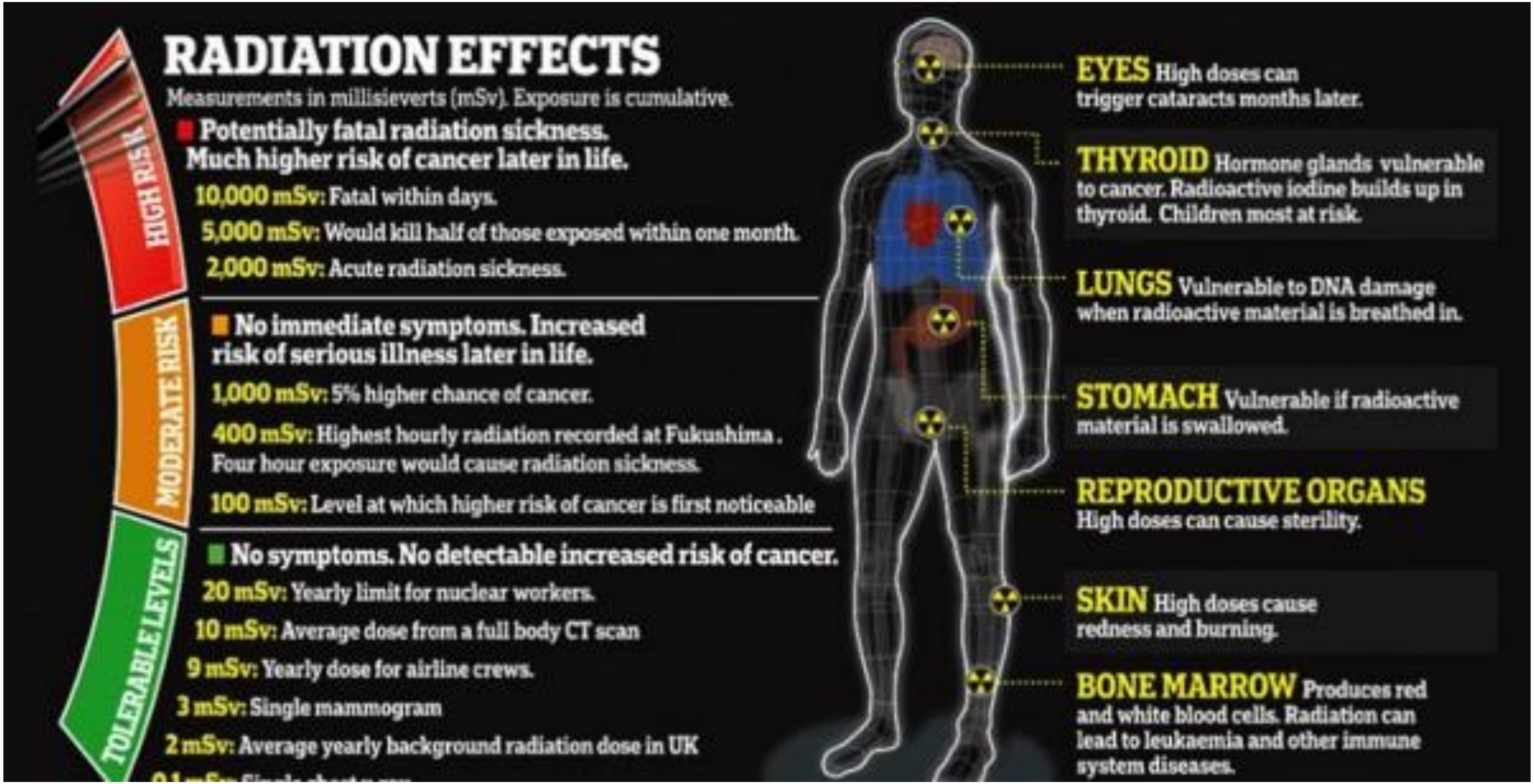
- At the dose levels accepted for radiation workers ***deterministic*** effects are not expected.

# Cosmic Radiation

***Chance (Stochastic) effects***

- This refers to the likelihood of the effects or effects' possibility of occurring,
- The larger the radiation dose, the bigger the possibility of the occurrence of the effect.
- These effects can be caused by both chronic and acute exposures.




RADIATION EFFECTS
Measurements in millisieverts (mSv). Exposure is cumulative.
HIGH RISK
Potentially fatal radiation sickness. Much higher risk of cancer later in life.
10,000 mSv: Fatal within days.
5,000 mSv: Would kill half of those exposed within one month.
2,000 mSv: Acute radiation sickness.
MODERATE RISK
No immediate symptoms. Increased risk of serious illness later in life.
1,000 mSv: 5% higher chance of cancer.
400 mSv: Highest hourly radiation recorded at Fukushima . Four hour exposure would cause radiation sickness.
100 mSv: Level at which higher risk of cancer is first noticeable
TOLERABLE LEVELS
No symptoms. No detectable increased risk of cancer.
20 mSv: Yearly limit for nuclear workers.
10 mSv: Average dose from a full body CT scan
9 mSv: Yearly dose for airline crews.
3 mSv: Single mammogram
2 mSv: Average yearly background radiation dose in UK
EYES High doses can trigger cataracts months later.
THYROID Hormone glands vulnerable to cancer. Radioactive iodine builds up in thyroid. Children most at risk.
LUNGS Vulnerable to DNA damage when radioactive material is breathed in.
STOMACH Vulnerable if radioactive material is swallowed.
REPRODUCTIVE ORGANS High doses can cause sterility.
SKIN High doses cause redness and burning.
BONE MARROW Produces red and white blood cells. Radiation can lead to leukaemia and other immune system diseases.

# Epidemiology

Several cohort studies have shown an increased incidence of cancer among pilots and cabin crew

In Europe two large mortality cohort studies, one amongst flight deck crew and one amongst cabin crew, together with a large cancer incidence study amongst Nordic pilots have been published.

An excess incidence of breast cancer has been reported among Finnish and Danish airline cabin crew,

with a standardised incidence ratio (SIR) of 1.9, 95% confidence interval (95% CI) 1.2 to 2.2 and SIR 1.6, 95% CI 0.9 to 2.7, respectively

# Epidemiology

- A similar cohort study of Canadian pilots has shown significantly increased incidences of prostate cancer (SIR 1.9, 90% CI 1.38 to 2.49) and acute leukaemia (SIR 4.72, 90% CI 2.05 to 9.31).
- Norwegian pilots have also been found to have excess risks for malignant melanoma (SIR 1.8, 95% CI 1.1 to 2.7) and non-melanoma skin cancer (SIR 2.4, 95% CI 1.3 to 4.0)
- Female cabin attendants in Finland, Norway, and in the small US cohort had a slightly increased overall cancer incidence compared with women in general
- As for pilots, there was a consistent excess risk of malignant melanoma that was observed

# Epidemiology

- Breast cancer was in excess in Finland, Denmark, and Iceland and in the small US cohort, but not in Norway.
- Together 105 breast cancer cases were observed versus 74.76 expected.
- The research carried out by the Finnish airline (Finnair) in the period of 1940 to 1992 showed that flight attendants have twice the risk of developing breast cancer compared to an average air passenger
- Analysis conducted for the “Yugoslav Airlines (JAT)”personnel concluded that ionising radiation could contribute in a small way to an excess risk of breast cancer among cabin crew

# Epidemiology

- Towards the end of October 2004 the British airline (British Airways) announced the results of the study revealing that 411 of its pilots had developed melanoma, bowel cancer or lung cancer due to cosmic radiation exposure.
- Cancer incidence data for male cabin attendants have been thoroughly reported only for the Norwegian cohort.
- In contrast to the two other aircrew groups, male cabin attendants had a clear excess cancer risk compared with the male national populations.
- The Norwegian cabin attendants had an excess risk of the alcohol-related upper respiratory and gastric tract cancers and of liver cancer; together 11 observed cases versus 1.7 expected cases.

# Epidemiology

- An excess risk of malignant melanoma was shared with the other aircrew groups.
- The Norwegian data on non-melanoma skin cancer do not include basal cell carcinoma, but the male cabin attendants had a marked excess risk of the other non-melanoma skin cancers.
- The subtype of non-melanoma skin cancer was not reported in the Norwegian study.
- It is noteworthy that two cases of Kaposi's sarcoma were observed in the small cohort of 187 Finnish male cabin attendants.

# Epidemiology

**<u>But on closer examination</u>**, these studies share the common problems of:

- a) small cohorts, and
- b) conspicuous confounders, e.g.
    - Reproductive factors such as nulliparity, in rates of Breast CA
    - Leisure time activities in rates of Melanoma
    - Lifestyle factors
    - Circadian disruption

# Epidemiology

- A meta-analysis of both published and unpublished cohort studies of air crew between 1986 and 1998 concluded that :

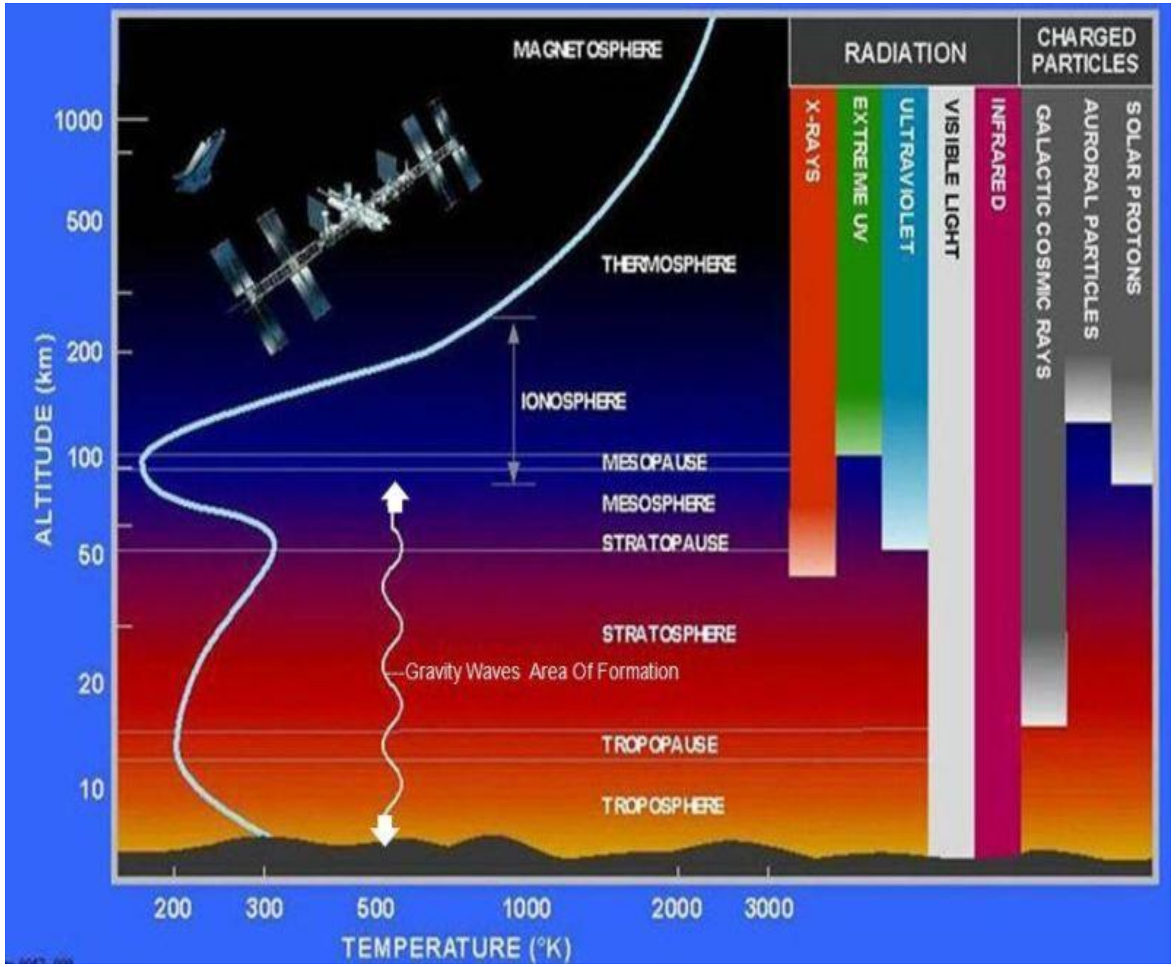
- Air crew seemed to be at risk of several types of cancer:

  - melanoma,
  - brain,
  - prostate, and
  - breast.

# Epidemiology

- But it was not possible, based on these studies, to pinpoint cosmic radiation as the culprit.

- The authors recommended that future studies must also compare risks within cohorts by:
  - flight routes,
  - work history, and
  - Exposures to:
    - cosmic and ultraviolet radiation,
    - electromagnetic fields, and
    - chemical substance



# ICAO

- ICAO **Annex 6 6.12** requires all airplanes intended to be operated above 15,000m (49,000ft) to carry equipment to measure and indicate continuously the dose rate of total cosmic radiation being received and the cumulative dose on each flight.

- ICAO **Annex 6 4.2.11.5** requires the operator to maintain records of flights above 15,000m (49,000ft) so that the total cosmic radiation dose received by each crew member over a period of 12 consecutive months can be determined.

# International Commission Radiological Protection (ICRP)

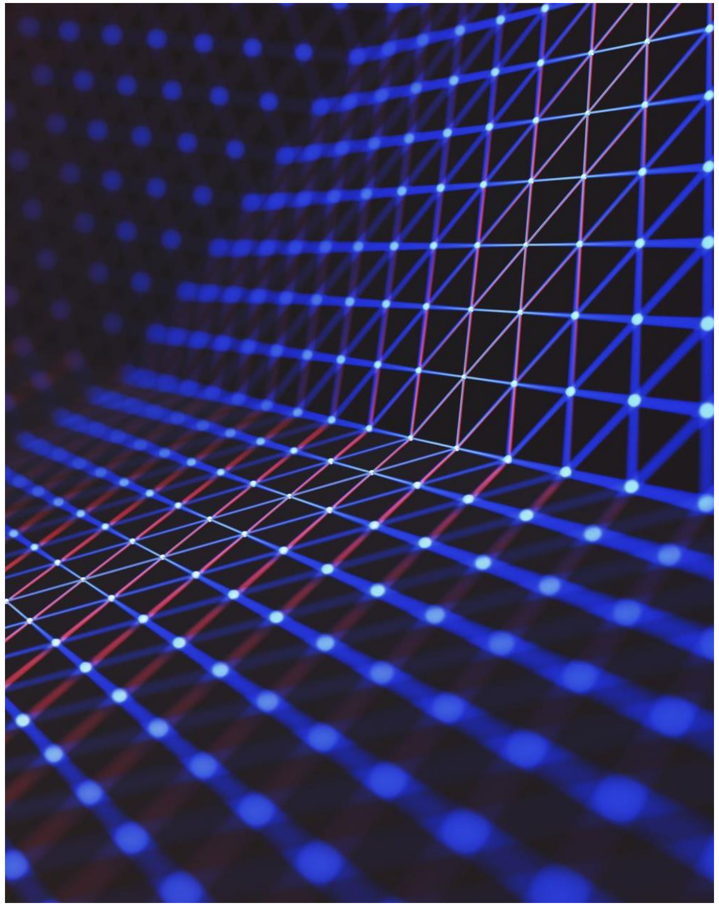
- The ICRP provides recommendations and guidance on protection against the risks associated with ionising radiation, but has no binding power.

- ICRP acknowledges aircrew to be occupationally exposed to radiation.

# Control of occupational exposure

Encourage pregnant air crew to declare their pregnancy status

CR exposure of the body is uniform, and the maternal abdomen provides no effective shielding to the foetus ====== the magnitude of equivalent dose to the foetus can be put equal to that of the effective dose received by the mother.



# (UK CAA) Implement computer programs to calculate:

- Dose estimates for routes flown, combined with staff roster information
- i.e. Date of departure, the location of departure, the flight profile detailing the time in ascent, cruise and descent and the arrival location.
- (These programs require updating, especially for the effect of solar modulation and for changes in geomagnetic field conditions).

# The European commission guidance recommends individual monitoring.

- The purpose of the monitoring is to ensure that **the annual doses do not exceed 6 mSv/ annum**
- A suitable cut off point would be where the assessment indicates a **maximum annual dose of 4 mSv**
- Where the air crew are liable to receive doses in excess of 4 mSv per annum, it is recommended that there should be monitoring of individual air crew member’s exposure using computer program prediction.

# The European commission guidance recommends individual monitoring.

- Where the air crew are liable to exceed 6 mSv/ annum, individual monitoring should be carried out.
- Operators should adjust an aircrew member's roster to reduce exposure with the aim of preventing, where possible, doses in excess of 6 mSv/annum.
- Records for individuals exposed to > 6mSv must be kept for a minimum of **30 years from the last annual exposure of > 6 mSv** (even if the individual concerned is deceased**) or until the individual is 75 years of age, whichever is the longer period of time.**

# Monitoring compliance (UK CAA)

- The operator should have a system of record keeping which should be detailed in the operations manual and which should be available for inspection by the CAA.
- **The radiation records should be kept for a 12 month period after the last complete 12 month period recorded, i.e. for 2 years**

# Monitoring compliance (UK CAA)

- This accord with the requirements to keep flight time limitation records for one year after the flight referred to.
- Records for individuals exposed to > 6mSv must be kept for a minimum of **30 years from the last annual exposure of > 6 mSv** (even if the individual concerned is deceased) **or until the individual is 75 years of age, whichever is the longer period of time.**

# EU - General considerations in control of occupational exposure

- Operators to educate and inform the crew regarding the risks of occupational exposure to radiation.
- Encourage female to report to the employer as soon as they are aware of their pregnancy.
- **Aircraft capable of operating at altitude >49 000ft should carry an active radiation monitor, which monitors levels of radiation.**

# EU - General considerations  in control of occupational exposure

- Air crew operating such high flying aircraft should be subject to the same general monitoring regime.
- No controls are necessary for an individual member of air crew whose annual dose can be shown to be shown to be < 1 mSv.
- (Note: airlines generally work in terms of block hours vs flying hours)

# International Best Practices (IBP)

**FAA regulations**

- There are no binding regulations concerning radiation within FAA rules.
- However, the FAA considers aircrews to be occupationally exposed to ionising radiation and has the same recommended limits as ICRP recommendations

# IBP

- **<u>The Law on Air Traffic of Serbia</u>** (Official Gazette of the Republic of Serbia, 2010) stipulates that :
  - *Work hours of air crew members on scheduled flights and regarding other commercial activities,*
  - *flight duration,*
  - *a period of time when a member of air crew is released of all duties,*
  - *annual leave of air crew members on scheduled flights and concerning other commercial activities and*
  - *a period of paid leave of air crew for the purpose of maintaining good psycho-physical shape*
- *shall closely be set forth by the minister responsible for traffic affairs*

# IBP

- According to the **Yugoslavian regulations**, concerning the limits of ionizing radiation exposure (Official Gazette of the Federal Republic of Yugoslavia, 1998),

- *“The basic natural radiation level /phon/ for a given location shall equal overall ionizing radiation from natural sources in the soil and cosmic radiation up to a level that has not been significantly raised by human activities”*

# IBP

**Joint Aviation Authority (Now EASA)**

- Agreed to co-operate in developing and implementing common safety regulatory standards and procedures.

- It issues Joint Aviation Requirements (JARs), which usually are implemented as national regulations.

- The European Radiation Protection Basic Safety Standards Directive [BSS96] is considered in JAR-OPS 1.390 [JAR01].

# IBP

**Nuclear and Radiation Legislation: South Africa**

- The South African Nuclear and Radiation industry is governed mainly by the Nuclear Energy Act (Act No. 46 of 1999) and the National Nuclear Regulator (NNR) Act (Act No. 47 of 1999).

- The NNR's policy for regulating radiation safety is in line with international consensus and requires that:

  - *The risks to both the workforce involved in licenced activities and the general public should not exceed prescribed limits for both normal operation and for potential accidents,*

  - *Both individual and population risks be maintained as low as reasonably achievable, (social and environmental factors being taken into consideration).*

# IBP

**Nuclear and Radiation Legislation: South Africa**

- These fundamental principles lead to a system of radiation dose limitation for persons occupationally exposed to radiation and for members of the public.

- Safety standards and regulatory practices adopted by NNR are in line with the International Atomic Energy Agency (IAEA) and the International Commission on Radiation Protection (ICRP) as well as other international norms and standards.

- The suite of IAEA safety standards and the current IAEA basic safety standards in particular, were used as references in the development of the South African Regulations on Safety Standards and Regulatory Practices.

# IBP

**<u>Nuclear and Radiation Legislation: South Africa</u>**

- According to the NNR Act, any person wishing to engage in any action which is capable of causing nuclear damage may apply to the NNR for a nuclear authorization (nuclear installation licence, certificate of registration or a certificate of exemption).

- Dose limits are applicable to a nuclear authorisation holder. The aim of the dose limits are:
    - To keep within acceptable limits the possibility of a chance effect as a result of exposure to radiation; and

    - To protect against any of the threshold effects of radiation exposure.

# Recommendations

**There are three fundamental principles in radiation protection:**

- Justification
- Optimisation
- Application of dose limits

# Recommendations

- According to Section 8(1) of the Occupational Health and Safety Act (OHSA) (Act 85 of 1993), as amended by Occupational Health and Safety Amendments Act (Act 181 of 1993) in the '<u>general duties of employers to their employees</u>':

<u>**Employers must ensure:**</u>

- *Provision and maintenance, as far as is reasonably practicable, of:*
  - *A safe environment, and*
  - *An environment that is without risk to the health of all employees (including pregnant females).*

# Recommendations

*These include, amongst other things:*

- *Taking such steps as may be reasonably practicable to:*
  - *Eliminate or mitigate any hazard or potential hazard to the safety or health of the employees, and*
  - *Make arrangements for ensuring the safety and absence of risk to health in connection with related work*

# Recommendations

## Control of occupational exposure: general considerations

- **Operators/Employers should make arrangements to :**
  - Give information and provide education regarding the risks of occupational exposure to radiation to their air crew.

  *(air crew being defined as flight crew, cabin crew and any person employed by the aircraft operator to perform a function on board the aircraft while it is in flight.)*

  - Make female air crew aware of the need to control doses during pregnancy and to notify their employer if they become pregnant so that any necessary dose control measures can be introduced.

# Recommendations

**When the crew is exposed to radiation which exceeds 1 millisievert a year:**

**Employers must:**

- Estimate the crew's exposure to cosmic radiation,
- Consider the estimated radiation exposure of crew members when drawing up the working schedule in order to reduce the radiation dose of crew members who have already been exposed to high-level of radiation,
- Familiarize crew members, those to whom it applies, with health risks related to the pursuit of their professional activities

# Recommendations

- Ensure that working schedule for female crew members, once they have been notified that they are pregnant, keep the foetus exposed to radiation as little as possible and ensure that the dose does not exceed 1 millisievert for the remainder of the pregnancy,

- Keep records on each individual and especially on crew members who are exposed to higher doses of radiation.

- Crew members have to be informed about the cosmic radiation doses every year and **upon retirement**.

# Recommendations

**<u>For aircrew that are likely to receive exposures in excess of 1 msv per annum:</u>**

**<u>The employer must:</u>**

- Assess the exposure of the crew concerned;
- Take into account the assessed exposure when organising working schedules with a view to reducing the doses of highly exposed aircrew;
- Inform the workers concerned of the health risks their work involves;
- Apply special protection for female aircrew during declared pregnancy.

# Recommendations

## Control of occupational exposure in high flying aircraft

- Aircraft capable of operating at altitudes greater than 15 km (49,000ft) should:
  - Carry an active radiation monitor, which monitors current levels of radiation, to detect any significant short-term variation in radiation levels during flight.
  - Such variations may arise as a result of solar flares, or other solar events, which can cause a sharp increase in the solar component of cosmic radiation, especially at altitudes above 15km.

***(Potential exposure resulting from such an event can be greatly reduced by a controlled descent if active monitoring is used.)***

# Recommendations

- Air crew operating such high flying aircraft should be subjected to the same general monitoring regime as for those operating between 8 and 15 km but account should be taken of the greater potential variability of dose.

- **Active monitoring may be used to:**

  - Assess the doses to which air crew are exposed (rather than using a computer program to predict dose) or

  - Simply to provide a warning of high dose rates.

# Recommendations

**Control of occupational exposures of pregnant women**

- Once the pregnancy is declared:

**The employer must:**

- Plan future occupational exposures such that the equivalent dose to the foetus is unlikely to be greater than 1 mSv during the remainder of the pregnancy.

*(The CR exposure of the body is essentially uniform and the maternal abdomen provides no effective shielding to the foetus).*

$E_D$ same for mother and child

# Recommendations

**Current IFALPA policy requires:**

- ICAO lead task-force to evaluate the possible descent procedures for a large number of aircraft in the event of a solar storm

# Recommendations

- Some operators have determined that pregnant aircraft crew should cease flying duties on declaration of pregnancy,
- South African Airways is one such operator
- This is with regard to the requirement of keeping doses low as reasonably achievable.

# Recommendations

- It should also be noted that the practice of grounding crew from the moment they declare pregnancy may be based on **<u>other aviation physiological risk factors</u>** to the mother and foetus, including:

  - circadian dysrhythmia,
  - hypoxia, dehydration,
  - noise,
  - vibration and turbulence,
  - mental fatigue and injury through manual handling and
  - exertion.

# Recommendations

- Although further studies are necessary to clarify the exact role of occupational exposure,
- All airlines should, as some companies do,
  - Estimate radiation dose,
  - Organize the schedules of crew members in order to reduce further exposure in highly exposed flight attendants,
  - Inform them about health risks, and
  - Give special protection to pregnant women.

# Recommendations

- Pregnant crewmembers can minimize occupational exposure to CR by working on:
    - short,
    - low-altitude, and
    - low-latitude flights.

# Conclusion

Aircrew have very unique working conditions.

Their work is often **shift work**, working at **high altitude**, and **high latitude**, with a possibility of **flights over different time zones;**

This exposes them to:

| | | |
|---|---|---|
| **Circadian disruption ,** | **Exposure to higher cosmic radiation**, and | **High risk of illnesses** |

# Conclusion

Our public today still seems insufficiently informed when it comes to hazards brought about by natural sources of radiation.

There need to be protection for aircrew from radiation to comply with occupational health and safety laws and regulations.

ACKNOWLEDGEMENTS

- ***Dr Lesego Bogatsu:*** Advisor, Senior Manager, SA Civil Aviation Authority and Invitational Lecturer, University of Pretoria
- ***Dr Thabani Nkwanyana***: Aviation Medical Examiner
- ***Dr Nozipho Sangweni:*** Reviewer, Former Chief Medical Officer, South African Airways

THANK YOU