Current Strategies of the Aviation Industry in Preventing the Exposure to Cosmic Radiation

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Abstract-* *It is feasible that passengers aboard airplane could occasionally be exposed to the sun's ionizing radiation because the sun has the ability to emit ionizing radiation. The specific variety of ionizing radiation that is produced in extraterrestrial environments is referred to as "cosmic ionizing radiation." When an airplane travels to higher altitudes, everyone on board, including the crew and passengers, is exposed to a greater quantity of cosmic radiation. The findings of this study offered improved methods for reducing the likelihood that passengers and flight crew may be exposed to cosmic radiation. It determined the level of perception held by the passengers as well as the level of satisfaction they held. Additionally, the strong association that exists between the degrees of perception and satisfaction was found to be identified by this research. In conclusion, the research came up with some improved strategies that were formulated based on the findings and implications of the study. A combined total of one hundred participants, including both passengers and crew members, took part in the investigation of the study using a mixed method of research. In addition to that, the data collection utilized the method of convenience sampling. As a consequence of this, there is a strong positive relationship, which is very significant, between the amount of satisfaction and the level of perception of the participants. It is anticipated that there would be a required amount of radiation that a person has to be exposed to as part of an enhanced strategy. For example, in the case of the aircraft company, the level of radiation rises as altitude increases. As a passenger, the possibility of being exposed is very low.

I. INTRODUCTION

Not only is the atmosphere of our planet essential for flight, but it also shields life from potentially lethal cosmic radiation such as ultraviolet or ionizing radiation that originates from outer space. The ability to emit electromagnetic and charged particles with high energy that can travel through the magnetosphere, rise to the upper atmosphere, and interact with the elements that make up the atmosphere comes from sources that originate from outside of our solar system. Both passenger and commercial airplanes are being harassed by particles with a high energy level. The origin of these particles can be traced back to cosmic rays. The vast majority of them have some kind of interaction with the magnetic field of the Earth, but a significant number of them are able to sneak past it and enter the atmosphere. An increase in radiation rate is produced by traveling to higher altitudes. Our focus was distributed among three distinct categories of widely used polymers. Polypropylene, polycarbonate, and polyamide 6.6 were some of the polymers that were used (Major & Boja, 2018).

While the wavelength of electromagnetic radiation has a considerable impact on how it interacts with matter, charged particles form a secondary radiation field in the atmosphere, which results in a cascade of secondary particles. This field can be thought of as a "secondary particle cascade." The ubiquitous Galactic Cosmic Radiation (GCR) component, for example, causes the production of a secondary radiation field. This field's ionization maximum is determined by a number of different factors, and it was initially measured at an altitude of approximately 15 kilometers under the existing conditions.

In addition, as atmospheric depth increases, the composition of this secondary atmospheric radiation field as well as the distribution of its energy changes. At the cruising altitudes that are used by civil aviation, the intensity of the radiation field is often still one to two orders of magnitude stronger than it is at sea level.

The primary components that determine shielding are a location's geomagnetic field, altitude, and the amount of solar activity. In addition to being essential for flight, the atmosphere of our planet also functions as a shield that protects life on Earth from the harmful effects of cosmic radiation such as ionizing radiation and ultraviolet radiation that travels through space. The ability to emit electromagnetic and charged particles with high energy that can traverse the magnetosphere, climb to the upper atmosphere, and interact with the elements that make up the atmosphere comes from sources that originate from beyond our solar system. While the wavelength of electromagnetic radiation has a considerable impact on how it interacts with matter, charged particles form a secondary radiation field in the atmosphere, which results in a cascade of secondary particles. This field can be thought of as a "secondary particle cascade." For example, the pervasive Galactic Cosmic Radiation (GCR) component generates a secondary radiation field. The ionization maximum of this secondary radiation field varies depending on a number of factors, but it was first recorded at an altitude of approximately 15 kilometers under the present conditions (Meier, 2020).

Even as far back as 1990, the International Committee on Radiological Protection (ICRP) put out the idea that radiation doses experienced by aircrews should be treated in the same manner as occupational radiation exposures (ICRP, 1990). This proposition was agreed by the European Union (EU) in 1996, and it was then integrated into EU Directive 96/29/EURATOM, which was published in 2000, and it became legally enforceable in all of the member states of the EU the following year (Euratom, 1996). The majority of the legally required radiation protection measures consisted of conducting an evaluation of the amount of radiation exposure each crew member was subjected to, taking that exposure into consideration when planning work schedules to reduce the doses received by highly exposed aircrew, informing workers about the health risks associated with their work, and capping the doses received by pregnant crew members at 1 mSv for the remainder of the prenatal period. All of these steps were taken to protect workers from the harmful effects of radiation exposure. Directive 2013/59/EURATOM was issued by the European Union in 2013, and it was intended to increase radiation safety regulations for aircrews working within the European Union (Euratom, 2014). The most recent set of recommendations from the International Committee on Radiological Protection (ICRP), which were published in 2007, served as the basis for the establishment of these guidelines. ISO 20785 is a set of standards that addresses the evaluation of an individual's exposure to cosmic radiation. These standards can be found here. The themes "Conceptual basis for measurements," "Characterization of instrument response," "Measurements at aviation altitudes," and "Validation of codes" are some of the ones that are covered by these standards (ISO, 202, 2019, 2015, 2019).

Flight crews face a risk of exposure to ionizing radiation on the job, the majority of which comes from galactic and cosmic radiation. It is generally accepted that supernovae are the principal generators of cosmic radiation in galaxies. Ionizing radiation can occasionally be caused by the sun, which can be experienced by passengers during flight. The term "cosmic ionizing radiation" refers to a specific kind of ionizing radiation that is produced in outer space (or cosmic radiation). The amount of radiation that reaches Earth is only a very minute fraction of the total. At higher flight altitudes, passengers and crew are subjected to a greater dose of cosmic radiation. According to the findings of the International Agency for Research on Cancer (IARC), which is part of the World Health Organization, ionizing radiation is one of the known causes of cancer in humans (WHO). Ionizing radiation is known to cause a variety of negative effects, including problems with reproduction. To be more specific, we are looking into the possibility that cancer and other reproductive problems are linked to the ionizing radiation that comes from space.

The vast majority of research on the effects of radiation on human health has been conducted on populations that have been exposed to significantly greater radiation doses from a variety of sources (atomic bomb survivors; patients who received radiation therapy). Although there are recommendations at the national and international levels, the United States does not have any formal dose restrictions in place for aircrew members.

II. PROCEDURE

- Research Design

This study uses the Predictive Flowchart as its Conceptual Framework. The variables used are the demographic profile of the participants, the level of perception, and the level of satisfaction of the participants. The independent variables in the study include the demographic profile such as age, gender, and other personal information of the participants while the dependent variable includes the levels of perception and satisfaction of the participants in the light of the study.

Utilizing various statistical techniques and tools, the survey questionnaire was used to assess the degree of perception as well as the degree of satisfaction as its output. As a result, an "Enhanced Strategy" was proposed.

- Methods of Research

A mixed method was used in this investigation based on the data collected. This research methodology employed a purposeful process of data collection, analysis, categorization, and tabulation to ascertain the current circumstances, practices, perceptions, processes, and precise interpretations regarding the data collected using statistical methods. The problems 1-5 utilized the quantitative approach because it best meets the goal of the investigation while the problem number 6 formulated strategies to prevent cosmic radiation in aviation. The study used various statistical tools per objective. In objective 1, frequency and percent distribution will be used. In objectives 2 and 3, Likert scale, mean and standard deviation are the most appropriate. In objective no. 4, Pearson correlation test and Regression Analysis will be used. Finally, in objective no. 5, formulation of strategies should be accomplished.

- Participants in the Study

This study focuses on the participants' perceptions in the aviation to prevent cosmic radiation. They are flight crew and passengers of various airlines. Primary data and information were conducted using survey. A total of one hundred two (100) participants were included to participate in the study, a sample population size of 50 for the passengers and 50 for the flight crew.

The proponent used convenience sampling method because it is efficient, and simple to implement. The participants are selected based on availability and willingness to take part.

- Data Gathering Instrument

The study conducted in various airlines wherein, there are 100 personnel involved under study. Upon approval of the letter of request to airline companies, the researcher-made questionnaire was conducted. The questionnaire has three parts.

The participant's demographic data is covered in the first section. The level of satisfaction with the existing approaches being used by the aviation industry to prevent exposure to cosmic radiation was covered in the second section, which also included feedback from the passengers, cabin staff, and flight crew. The third component is how the passengers, cabin crew, and flight crew perceive the present methods used by the aviation sector to limit exposure to cosmic radiation. The Likert scale, which asked participants to rate items on a scale of one to four, with one representing the lowest rating and four the highest, was commonly used on survey questionnaires. The comprehension, level, and expertise of the participants were depicted using the research findings. Acquired values were represented by adjective equivalence.

- Statistical Treatment of Data

The following formula used to treat, analyzed, and calculated the relationship of variables in the research:

1. Percentage and Frequency Count Distribution. This method was used to identify the demographic profile of the participants using the following formula by Gujarati (2003):

$$P = \frac{f}{n} \ x\, 100$$

where:

P = percentage

f = frequency

n = number of selected transacting members

2. Mean. This method was used to determine the average value of a set of values, which is the sum of all values divided by the number of values using the following formula by Gujarati (2003).

Mean = $\bar{x} = \frac{\Sigma x}{n}$

where:
$\bar{x}$ = (read as 'x bar') is the mean of x values
Σx = sum of all the x values
n = number of x values

3. Likert Scale. This measurement was used to determine the level of satisfaction and perception of the passengers and flight crew to the current strategies being implemented by the aviation in preventing the exposure to cosmic radiation with its verbal interpretation that was shown below (Table 1) by Gujarati (2003).

Table 1
FOUR POINT LIKERT SCALE

Assigned Points	Numerical Ranges	Verbal Interpretations	
4	3.51 - 4.00	Very Satisfied	Very Aware
3	2.51 - 3.50	Satisfied	Aware
2	1.51 - 2.50	Slightly Satisfied	Slightly Aware
1	1.00 - 1.50	Not Satisfied	Not Aware

4. Standard Deviation. This method was used to determine the measure of the amount of variation or dispersion of a set of values using the following formula by Gujarati (2003).

$$s = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n - 1}}$$

where:
s = sample standard deviation
Σ = (known as "sigma") sum of...
$\bar{x}$ = sample mean
n = number of scores in sample

5. Pearson Correlation Coefficient. It is the test for the significant relationship between explanatory variables and explained variables. To measure the correlation between variables, the Pearson Correlation Coefficient was employed. It is used to test the significant relationship between the level of satisfaction and perception of the passengers and flight crew to the current strategies being implemented by the aviation authorities/industries in preventing the exposure to cosmic radiation. The value of r close to unity in magnitude implies a good correlation or linear association between x and y, whereas values near zero indicate little or no correlation. Pearson Correlation Coefficient was done using the following formula by Gujarati (2003):

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

where:
N = number of pairs of scores
$\sum xy$ = sum of the products of paired scores
$\sum x$ = sum of x scores
$\sum y$ = sum of y scores
$\sum x^2$ = sum of squared x scores
$\sum y^2$ = sum of squared y score

5. Regression analysis**.** Allows for investigating the relationship between variables. Usually, the variables are labelled as dependent or independent. An independent variable is an input, driver or factor that has an impact on a dependent variable (which can also be called an outcome.

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2}$$

$$a = \frac{\sum y - b\sum x}{n}$$

The formula for calculation is Y = a + bX + E, where Y is the dependent variable, X is the independent variable, a is the intercept, b is the slope, and E is the residual. Regression is a statistical tool to predict the dependent variable with the help of one or more independent variables.

III. RESULTS

Table 1
FOUR POINT LIKERT SCALE

Assigned Points	Numerical Ranges	Verbal Interpretations	
4	3.51 - 4.00	Very Satisfied	Very Aware
3	2.51 - 3.50	Satisfied	Aware
2	1.51 - 2.50	Slightly Satisfied	Slightly Aware
1	1.00 - 1.50	Not Satisfied	Not Aware

The age distribution of the participants was presented in Table 3, which outlined the demographic profile of the study's participants. It was made abundantly evident that the bulk of the participants are between the ages of 41 and 50, with a frequency of either 48 or 47.50% of the total. This suggests that people in their middle ages have a passion for seeing new places and make the most of their lives.

Table 4
FREQUENCY AND PERCENTAGE OF THE PARTICIPANTS' PROFILE IN TERMS OF GENDER

GENDER	FREQUENCY	PERCENTAGE
MALE	64	63.40
FEMALE	37	36.60
TOTAL	101	100.00

The demographic profile of the participants, broken down according to gender, is presented in Table 4. The frequency of male participants is 64, which corresponds to 63.40% of the total, while the frequency of female participants is 37, which corresponds to 36.60% of the total. It suggests that individuals from the Philippines have different motivations than females for traveling outside of their country.

Table 5
FREQUENCY AND PERCENTAGE OF THE PARTICIPANTS' PROFILE IN TERMS OF CATEGORY

CATEGORY	FREQUENCY	PERCENTAGE
PASSENGER	70	69.30
CABIN CREW	15	14.90
FLIGHT CREW	16	15.80
TOTAL	101	100.00

Table 5 presented an illustration of the demographic profile of the participants based on the category to which they belonged. According to the table, passengers make up 69.30% of the total, while flight crew members have a frequency of 15.80% and cabin crew members have a frequency of 14.90% respectively. This is due to the fact that there are a large number of passengers who might readily take part in this study, whereas members of the flight crew and cabin crew are difficult to find.

Table 6
DEMOGRAPHIC PROFILE IN TERMS OF THE NUMBER *OF TIMES BEING AN AIRPLANE PASSENGER*

NO. OF FLYING AS PAX	FREQUENCY	PERCENTAGE
ONCE A YEAR	44	62.86
ONCE A MONTH	1	1.43
2-3 TIMES A YEAR	25	35.71
TOTAL	70	100.00

Table 6 Illustrated the demographic profile of the participants in terms of the number of times being an airplane passenger. Based on the table, most of the passengers fly once a year with a frequency of 44 or 62.86%, followed by two-three (2-3) times a year with a frequency of 25 or 35.71% and lastly is once a month with one (1) passenger or 1.43% respectively.

Table 7
THE FREQUENCY OF THE PARTICIPANTS IN TERMS OF THE LENGTH *OF SERVICE AS FLIGHT CREW*

LENGTH IN SERVICE AS FLIGHT CREW	FREQUENCY	PERCENTAGE
10 years and above	9	56.25
7-9 years	4	25.00
4-6 years	2	12.50
Less than 3 years	1	6.25
TOTAL	16	100.00

Table 7 Illustrated the length in service as flight crew. It is clearly stated that majority of the participants are 10 years and above with in the service with a frequency of nine (9) or 56.25%, followed by 7-9 years in service with a frequency of 4 or 25% , 4-6 years in service with a frequency of two(2) or 12.50% and lastly, less than 3 years with one(1) or 6.25% respondent.

Table 8
MEAN DISTRIBUTION ON THE LEVEL OF SATISFACTION OF THE PASSENGERS AND FLIGHT CREW

STATEMENTS	MEAN	SD	INTERPRETATION
1. I am satisfied with the instruments and strategies used to measure radiation exposure in the atmosphere to protect passengers, cabin, and flight crew.	2.34	1.15	Slightly Satisfied
2. I am satisfied with the radiation protection measures include individual dose assessment of passengers, cabin and flight crew, roster planning with a view to reducing the doses of the highly exposed crew, and advisory information.	2.30	1.16	Slightly Satisfied

3. I am satisfied because we are always guided by the authorities when we interact with electronics.	2.25	1.15	Slightly Satisfied
4. I am satisfied with the equipment used to protect the health of the passengers, cabin, and flight crew.	2.24	1.16	Slightly Satisfied
5. I am satisfied with the displayed precautions in the flight can be observed at all times.	2.24	1.12	Slightly Satisfied
6. I am satisfied with the given information by the authorities for us to have an awareness in the total radiation exposure or an electronic device, respectively, depends on the intensity of the corresponding radiation field in terms of dose rate and the duration spent in this field.	2.16	1.10	Slightly Satisfied
7. I am satisfied and understand that flights could be delayed until the additional radiation component due to a solar radiation event has decreased significantly in order to reduce the time spent in the radiation field in the atmosphere.	2.16	1.09	Slightly Satisfied
TOTAL	2.24	1.13	Slightly Satisfied

Table 8 illustrates the level of satisfaction of passengers and flight crew to the current strategies being implemented by the aviation industry/authority in preventing exposure to cosmic radiation. They received a mean score of 2.24, with a standard deviation of 1.05, which can be interpreted as meaning that they are only slightly satisfied with the current strategies.

The future of aviation safety management is data fusion (Norman, 2022., Mangortey et al., 2019). It would be essential to obtain safety reports from pilots, flight attendants, dispatchers, and maintenance staff to evaluate the severity of the event if an aircraft experienced extreme turbulence during flight that resulted in injuries to passengers and potential structural damage to the airframe. Also, it would make sense to combine these reports with those from air traffic controllers to gain a comprehensive picture of the safety incident.

Table 9
MEAN DISTRIBUTION ON THE LEVEL OF PERCEPTION OF THE PASSENGERS AND FLIGHT CREW TO THE CURRENT
STRATEGIES BEING IMPLEMENTED BY AVIATION
IN PREVENTING THE EXPOSURE TO COSMIC
RADIATION

STATEMENTS	MEAN	SD	INTERPRETATION
1. Ionizing radiation in the atmosphere has impact on human health. For this reason, radiation exposure of passengers, especially cabin and flight crew are regarded as occupational.	2.25	1.07	Slightly Aware
2. Radiation protection measures include individual dose assessment of passengers, cabin and flight crew, roster planning with a view to reducing the doses of the highly exposed crew, and advisory information.	2.23	1.10	Slightly Aware
3. When cosmic radiation interacts with electronics, different types of damage can be observed: total dose effects, displacement damage effects, and single event effects. Regarding atmospheric environments primarily the latter were considered.	2.16	1.13	Slightly Aware
4. In electrical devices, single particles randomly interact with semiconducting components and immediately generate free charge carriers causing erroneous currents.	2.10	1.08	Slightly Aware
5. Non-destructive soft errors such as Single Event Upsets (SEU) and hard errors such as Single Event Latch-Ups (SEL) or Single Event Burnouts (SEB) which lead to permanent damage of the device can be observed. Memory structures are particularly vulnerable to such events and can experience alterations.	1.95	0.99	Slightly Aware

6. The total radiation exposure of an individual or an electronic device, respectively, depends on the intensity of the corresponding radiation field in terms of dose rate and the duration spent in this field.	2.19	1.08	Slightly Aware
7. Transport of passengers or freight is not time-critical, flights could be delayed until the additional radiation component due to a solar radiation event has decreased significantly in order to reduce the time spent in the radiation field in the atmosphere.	2.10	1.05	Slightly Aware
	2.15	1.07	Slightly Aware
TOTAL			

Table 9 Illustrates the level of perception of the passengers and flight crew to the current strategies being implemented by aviation in preventing exposure to cosmic radiation garnering a mean score of 2.15 and standard deviation of 1.00 which shows that the participants are slightly aware.

According to Norman (2022) the generated safety intelligence is essential for efficient safety management. From voluntarily submitted safety reports by all parties. If there is an imbalance in reporting because of a perceived lack of trust in the current reporting mechanisms by some stakeholders, the process of continual improvement in safety is hampered. Top management should look for occupational groups that are less likely to voluntarily disclose safety hazards and use the best practices to encourage them to do so. Confidentiality policies and rewarded no-blame reporting are examples of procedures that foster trust.

Table 10
PEARSONS CORRELATION COEFFICIENT RESULTS ON THE RELATIONSHIP BETWEEN THE LEVEL OF SATISFACTION
AND PERCEPTION OF THE PASSENGERS AND FLIGHT CREW

	r	sig value	p value	Decision	Interpretation
Level of Satisfaction and Perception of Passengers and flight crew	0.87	0.00	<0.01	Reject Ho	Highly Significant

Table 10 showed the connection between the perception and degree of satisfaction of the passengers and flight crew regarding the present aviation radiation protection measures in use. It also reveals the correlation coefficient (r), which is 0.87 and indicates a strong positive correlation with a very significant sig value of 0.00. This indicates that there is a strong relationship between the perception and satisfaction of the passengers and flight crew about the current aviation tactics being used to reduce exposure to cosmic radiation.

The percentage of variance found was considerably influenced by organizational safety values, which had the strongest predictive association with voluntary reporting. Because rules have a considerable impact on how employees see their workplaces, it is likely that management will focus on policies that entrench safety ideals as essential company activities. Employee perceptions of their behavior when reporting safety incidents and their general comprehension of the organization's safety culture bear this out. In contrast to individuals who work in an unjust environment, employees who experience a high level of psychological safety are more likely to be willing to openly communicate and disclose information (Norman, 2022., Naor et al., 2020; Pfeiffer et al., 2010). All interested parties gain from this.

The National Institute for Occupational Safety and Health (2023) confirmed that we do not know what causes the majority of the health problems that could be linked to radiation. These health problems include some types of cancer as well as reproductive health difficulties such as miscarriage and birth deformities. If you are exposed to cosmic ionizing radiation and have certain health problems, we are unable to determine whether or not they were caused by the conditions in which you worked or by another factor. Thus, everyone is encouraged to be aware of the causes most especially to the passengers, crew, and other people at the aircraft. This is also the main responsibility of the aircraft companies to make all aware of this information for health and safety purposes.

CONCLUSION

Based on the garnered results, the following conclusions are drawn:

1. The bulk of the participants are between the ages of 41 and 50. Male participants make up the majority of the people who took part in the study. When broken down by type, the vast majority of those who took part were passengers. Majority of the participants fly at least once every year. They have been in the service for 10 years or more.
2. The participants are slightly satisfied with the current strategies implemented by the aviation industry in preventing exposure to cosmic radiation.
3. The participants are slightly aware of the current strategies implemented by the aviation industry in preventing exposure to cosmic radiation.
4. There is a strong positive correlation between the level of satisfaction and the level of perception of the participants and it is highly significant.

RECOMMENSATIONS

1. For slightly satisfied participants with the current strategies implemented, check the space weather before taking off. Very few passengers only do that, but airlines always do. Airlines varied flight paths to lower altitudes because of predicted solar activity, particularly SEP events during solar flares.
2. Consider the galactic radiation from supernovae around you but try not to let it spoil your trip. There's a fine line between "Right to know" and "Nice to know" things.
3. For slightly aware participants, create an account for an online tool that allows individuals who are concerned to calculate their personal cosmic radiation exposure levels in specific routes.
4. Protect yourselves with more frequent medical check-ups if you are worried.
5. Bidding for a flight schedule for crew members, to reduce cosmic radiation exposures is complicated, because reducing one's exposure may increase another. Seniority, lifestyle, and personal issues may also affect the ability to make these choices.
6. For Pilots, reduce the time working on very long flights, flights at high latitudes, or flights which fly over the poles. These are flight conditions or locations that tend to increase the amount of cosmic radiation the crew members are exposed to. Calculate the usual cosmic radiation exposures to estimate the effective dose from galactic cosmic radiation (not solar particle events) for a flight.

7. For pregnant flight attendants, or planning a pregnancy, it is important to consider work exposures, including cosmic radiation. If pregnant and aware of an ongoing solar particle event when you are scheduled to fly, you may want to consider trip-trading or other rescheduling actions, if possible, the first trimester may be linked to increased risk of miscarriage.
8. For Airlines that prefer polar routes because of shorter distance with lower head winds, meaning shorter journey times and lower fuel costs, must establish rotation of staff around those flight routes.
9. Airline manufacturers/industry increasingly use carbon-fiber based composites to build aircraft because of its strength and low weight, and much better protection against cosmic radiation than standard aluminum and metal alloys.
10. As a passenger/frequent flyer you have nothing to worry about. But, for your personal cosmic radiation monitoring you must not exceed 0.34 mSv (34 mrem) per year.

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REFERENCES

[1] Baczynska, K.A.; Brown, S.; Chorley, A.C.; O'Hagan, J.B.; Khazova, M.; Lyachev, A.;Wittlich, M. (2020). In-Flight UV-A Exposure of Commercial Airline Pilots. Aerosp. Med. Hum. Perform 91, 501–510. [CrossRef].

[2] Bodewein, L.; Schmiedchen, K.; Dechent, D.; \\\\ Stunder, D.; Graefrath, D.; Winter, L.; Kraus, T.; Driessen, S.(2019). Systematic review on the biological effects of electric, magnetic and electromagnetic fields in the intermediate frequency range (300 Hz to 1 MHz). Environ. Res. 171, 247–259.[CrossRef] [PubMed].

[3] Cadilhac, P.; Bouton, M.-C.; Cantegril, M.; Cardines, C.; Gisquet, A.; Kaufman, N.; Klerlein (2017). M. In-Flight. Ultraviolet Radiation on Commercial Airplanes. Aerosp. Med. Hum. Perform 88, 947– 951. [CrossRef]

[4] Chorley, A.C.; Baczynska, K.A.; Benwell, M.J.; Evans, B.J.W.; Higlett, M.P.; Khazova, M.; O'Hagan, J.B. Occupational Ocular UV Exposure in Civilian Aircrew. Aerosp. Med. Hum. Perform. 2016, 87, 32–39.[CrossRef] [PubMed].

[5] EURATOM. Council Directive 96/29/EURATOM of 13 May 1996 Laying Down the Basic Safety Standards for Protection of the Health of Workers and the General Public against the Dangers Arising from Ionizing Radiation. Off. J. Eur. Communities 1996, 159, 10–11.

[6] EURATOM. Council Directive 2013/59/EURATOM of 5 December 2013 Laying Down the Basic Safety Standards for Protection of the Health of Workers and the General Public against the Dangers Arising from Exposure to Ionizing Radiation and repealing. Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom.O_. J. Eur. Communities 2014, 57, 1–73. The German Aerospace Center

M-42 radiation detector—A new development for applications in mixed radiation fields. Rev. Sci. Instrum. 2019, 90, 125115. [CrossRef] [PubMed

(Handbook)

[7] Gill, J. (2020). Why pilots and flight attendants have higher risk skin cancer. In: https://utswmed.org. ICRP. 1990 Recommendations of the International Commission on Radiological Protection—ICRP Publication 60. Ann. ICRP 1991, 21, 1–3. ICRP. P103: The 2007 Recommendations of the International Commission on Radiological Protection; Elsevier: Amsterdam, The Netherlands, 2007; pp. 1–332.

[8] Hess, V.F. Über Beobachtungen der durchdringenden Strahlung bei sieben Freiballonfahrten. Phys. Z. 1912, XIII, 1084.

[9] International Commission on Non-Ionizing Radiation Protection. ICNIRP statement—Protection of workers against ultraviolet radiation. Health Phys. 2010, 99, 66–87. [CrossRef] 51. Di_ey, B.L.; Roscoe, A.H. Exposure to solar ultraviolet radiation in flight. Aviat. Space Environ. Med. 1990, 61,1032–1035. [PubMed]

[10] ISO. ISO 20785-1:2020 Dosimetry for Exposures to Cosmic Radiation in Civilian Aircraft—Part 1: Conceptual Basis for Measurements; International Organization for Standardization: Geneva, Switzerland.

[11] ISO. ISO 20785-2:2020 Dosimetry for Exposures to Cosmic Radiation in Civilian Aircraft—Part 2: Characterizationof Instrument Response; International Organization for Standardization: Geneva, Switzerland, 2019.

[12] ISO. ISO 20785-3:2015 Dosimetry for Exposures to Cosmic Radiation in Civilian Aircraft—Part 3: Measurements at Aviation Altitudes; International Organization for Standardization: Geneva, Switzerland, 2015.

[13] ISO. ISO 20785-4:2019 Dosimetry for Exposures to Cosmic Radiation in Civilian Aircraft—Part 4: Validation of Codes. International Organization for Standardization: Geneva, Switzerland.

[14] Major, A, A. M., & Boja, D. (2018). What can cosmic radiation cause in polymers? *IOP Conference Series.Materials Science and Engineering, 448*(1) doi: https://doi.org/10.1088/1757-899X/448/1/012057.

[15] Meier, M. M., Copeland, K., Klöble, K.,E.J., Matthiä, D., Plettenberg, M. C., Schennetten, K., . . . Hellweg, C. E. (2020). Radiation in the Atmosphere—A hazard to aviation safety? *Atmosphere, 11*(12), 1358. doi: https://doi.org/10.3390/atmos11121358

[16] Nakagawara, V.B.; Montgomery, R.W.; Marshall, W.J.O. Optical Radiation Transmittance of Aircraft Windscreens and Pilot Vision. In FAA Report. DOT/FAA/AM-07/20; 2007. Available online: https://www.faa.gov/data_ research/research/medhumanfacs/oamtechreports/2000s/media/200720.pdf.

[17] National Council on Radiation Protection and Measurements. *Ionizing radiation exposure of the population of the United States. Report No. 160. Recommendations of the National Council on Radiation Protection and Measurements (NCRP).* Bethesda, MD: National Council on Radiation Protection and Measurements, 2009.

[18] Radio Technical Commission for Aeronautics (2020). RTCA DO-160G. RTCA T4—Environmental Conditions and Test Procedures for Airborne Equipment; Radio Technical Commission for Aeronautics: Washington, DC, USA.

[19] Regener, E.; Pfotzer, G. Vertical Intensity of Cosmic Rays by Threefold Coincidences in the Stratosphere. Nature 1935, 136, 718–719. [CrossRef]. Sanlorenzo, M.; Vujic, I.; Posch, C.; Cleaver, J.E.; Quaglino, P.; Ortiz-Urda, S. The risk of melanoma in pilots and cabin crew: UV measurements In flying airplanes. JAMA Dermatol. 2015, 151, 450–452. [CrossRef].

[20] Scenhir Scientific Committee on Emerging Newly Identified Health Risks (2015). Opinion on Potential Health Effects of Exposure toElectromagnetic Fields (EMF); European Commission, DG Health and Food Safety: Luxembourg.

[21] Schennetten, K.; Meier, M.M.; Scheibinger, M. Measurement of UV radiation in commercial aircraft. J. Radiol. Prot. 2018, 39, 85–96. [CrossRef].

[22] Susumu, S., Wickramasinghe, N. K., Tatsuhiko, S., & Daikou, S. (2021). Estimate of economic impact of atmospheric radiation storm associated with solar energetic particle events on aircraft operations. *Earth, Planets and Space (Online), 73*(1) doi: https://doi.org/10.1186/s40623-021-01377-5

[23] Tezari, A., Paschalis, P., Stassinakis, A., Mavromichalaki, H., Karaiskos, P., Gerontidou, M., . . . Dierckxsens, M. (2022). Radiation exposure in the lower atmosphere during different periods of solar activity.Atmosphere,*13*(2), 166. doi: https://doi.org/10.3390/atmos13020166.

[24] Usoskin, I.G.; Mursula, K.; Kangas, J.; Gvozdevsky, B. On-Line Database of Cosmic Ray Intensities. In Proceedings of the 27th International Cosmic Ray Conference, Hamburg, Germany, 7–15 August 2001; p. 3842.

[25] Zarrouk N, Bennaceur R. Estimates of cosmic radiation exposure on Tunisian passenger aircraft. Radiat Prot Dosimetry. 2008;130(4):419-26. doi: 10.1093/rpd/ncn098. Epub 2008 Mar 28. PMID: 18375944.

[26] IAEA in: www.iaea.org/newscenter/news/orpas-mission-to-philippines- highlights-efforts-to-enhance-radiation-protection-of-workers. Retrieved April 10, 2023

[27] Eulinia M. Valdezco, M.Sc.PNRI DOST www.irpa.net/irpa10/cdrom/01232.pdf

[28] C.Scheibler, S.M. Toprani, I.Mordukhovich, M. Schaefer, S. Staffa, Z.D. Nagel, E. McNeely, Cancer risks from cosmic radiation exposure in Flight A review www.ncbi.nlm.nih.gov/pmc/articles/PMC9723364/

[29] FAA Advisory Circular In-Flight Radiation Exposure www.faa.gov/documentlibrary/media/advisory_circular/ac_120-61b.pdf