Te Matataua

The Scouting Party of Air Power

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Cosmic Radiation Effects on Air Operations

It can affect aircrew, and the modern avionics we depend on

The Concorde, which flew at high altitudes, had radiation sensors fitted so pilots could descend to a safer altitude, when the cosmic radiation dose limit was high due to solar events. This action reduced the biological effects of cosmic radiation; but cosmic radiation can also adversely affect satellite systems, communications, and aircraft avionics systems.

Cosmic Radiation increases with altitude

Military aircraft are dependent on its sensors, and systems technology. Capabilities can be significantly affected by malfunctioning electronic equipment; the aircraft itself may be fit to fly, but unless its technology is working effectively and consistently, then mission objectives will not be achieved.

Cosmic radiation originates from two sources: the Sun, and from outside the solar system. The Sun generates low energy cosmic radiation whereas cosmic radiation coming from outside the solar system comprises high energy particles that constantly bombard Earth from all directions.

The Sun also produces electromagnetic radiation that can affect electrical systems if large bursts are directed towards Earth. The famous Carrington solar flare of 1859 sent a massive cloud of charged particles towards Earth causing enormous electrical currents to surge through, and severely damage, communications systems.

In May 1967 a solar flare jammed US ballistic missile early warning radars. Initially thinking the Soviet Union was responsible, the USAF launched nuclear armed aircraft as a precaution[1]. In 1989 the state of Quebec, Canada was blacked out for nine hours due to a solar event. Clearly, space weather can affect military air operations.

Space weather describes the range of solar (Sun) events affecting Earth as follows[2]:

- Coronial Mass Ejections (CMEs): explosions of plasma that take 1-2 days to reach Earth that create geomagnetic storms affecting power grids, avionics, GPS applications and satellite systems.
- Solar flares: brief eruptions of intense electromagnetic radiation, taking minutes to reach Earth, which can degrade satellite communications, radar and high frequency radio communications.
- Solar particle events: bursts of heavy particles that increase the radiation level at high altitudes affecting communications and aircrew.
- Solar winds: plasma continuously flowing from the Sun that can enhance or degrade the effects of solar events described above.

The Earth's magnetosphere (the magnetic flux lines surrounding the Earth) provides partial protection to solar events as it deflects particles towards the poles.

Cosmic radiation is divided into two categories: primary cosmic radiation that affects space based devices (satellites); and secondary cosmic radiation that enters the atmosphere where some particles then interact with the molecules that make 'air' to produce cascades (showers) of lower energy particles such as neutrons.

Neutron density peaks at an altitude of 60,000 feet, reducing to about 1/3 peak level at 30,000 feet and reducing further to about 1/400 peak level on the Earth's surface[3]. Cosmic radiation density is therefore higher at the poles than the equator and increases with altitude. It is these neutrons that can affect modern electronic components.

Modern electronic components are miniaturised, have high storage capacity and low power consumption, which allows military aircraft systems to be small, fast and powerful. Miniaturised components comprise computer chips and storage devices that use semi-conductors, such as transistors, which can be as small as tens of atoms thick. Miniaturisation of electronic components allows many millions of transistors to be packed into extremely small chips.

System errors that occur during flight are often investigated after the aircraft has landed, usually by running built-in test programs or using test equipment in a servicing bay. Faulty components will be replaced or repaired, but in some cases testing will not find the fault; and either the unit is deemed serviceable and re-fitted to the aircraft or it is sent to the manufacturer for further testing. There can be many causes of failures in electronic components, such as: cracks in circuit boards, corrosion, or the formation of metal whiskers in non-lead solder. It is the potential sensitivity to secondary cosmic radiation that makes faults difficult to trace.

Secondary cosmic radiation can cause Single Event Effects (SEEs)[4] that can be the result of neutrons impacting atoms within a semiconductor, where the resulting debris shower can destroy one or more of its transistors. A single energetic particle striking an atom within a semiconductor can cause a *hard error* that is permanent and cannot be restored by a reset, or a *soft error* that can be recovered in flight with the circuit behaving normally. For example, a soft error can occur when an energetic particle flips the value of a single memory cell, which can be corrected by overwriting it.

Cosmic radiation dose rates for aircrew flying less than 1000 hours per year and at normal airline altitudes can be between 3 to 7 millisieverts (mSv) per year[5], which is less than the legislated occupational effective dose limit of 100mSv over five years. Maximum effective dose limits for pregnant women are reduced to 1mSv[6] in a year in excess of the background rate from natural sources, which is about 2mSv per year.

A millisievert (mSv) is a unit of measurement of radiation dose, where high levels of accumulated radiation in an individual can be harmful.

Aircrew scheduling and flying rates should be at a level that does not expose personnel to radiation levels higher than occupational exposure limits. Careful planning may be required when intending to fly at high altitudes, or during Antarctic ops as the magnetosphere deflects particles towards the pole, which elevates the level of cosmic radiation. While making a pretty aroura, the recent CME that occurred on 10 Sep 2017 would have exposed people flying at 40,000ft at high latitudes of up to 10mSv of radiation[7].

Space weather reports and forecasting should be considered for inclusion in aircrew pre-mission briefings as cosmic radiation can affect radio communications, radar imagery and aircraft systems. To get a real time space weather report, visit www.spaceweather.com.

Key Points

- Aircrew are exposed to higher levels of cosmic radiation, but below occupational limits, with reduced limits for pregnant aircrew.
- Neutrons, created from interactions of cosmic radiation with air molecules, can affect modern avionics systems.
- Space weather forecasting is useful to predict communication and systems degradation.

References

1. Australian Sky & Telescope Jan 2017.
2. US Government national space Weather strategy, October 2015.
3. Boeing, single event effects in avionics, presented to C-17 program, 16 Dec 98.
4. Atmospheric Radiation Effects on Avionics – An analysis of NFF errors by R. Bolinder, 29/6/13.
5. The exposure of NZ aircrew to cosmic radiation, NZ national radiation laboratory information sheet 19, Feb 1998.
6. NZ Radiation Safety Act 2016
7. spaceweather.com, accessed 13 Sep 17.

APDC Update

The APDC has called for papers for Volume 4 of the RNZAF Journal. Topics may be broad, but should relate in some manner to air power or regional security. The APDC is happy to suggest topics to those who prefer a question to analyse. Contact the APDC via: ohapdc@nzdf.mil.nz