

Impacts of space weather on aviation

CAP 1428

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Revision history

Issue 1

September 2016

CAP1428 is introduced to provide guidance to flight operators and other industry stakeholders on the likely impacts of space weather on aviation. Mitigation strategies through company Safety Management Systems are strongly encouraged.

Issue 2

October 2020

CAP1428 is revised to add details relating to ICAO Space Weather Advisories and Met Office Space Weather Products and Services, and to provide guidance on Safety Risk Assessments for industry when considering the threat of a severe space weather event.

Foreword

Civil Aviation Authority (CAA) Civil Aviation Publications (CAPs) are based upon national and European Union (EU) legislation and non-legislative regulatory material, such as ICAO Standards and Recommended Practices. They are published to provide UK industry with:

- a) guidance and clarification on the means of achieving compliance with global, UK and European regulatory requirements, and where applicable:
- b) details of United Kingdom (UK) 'Alternative Means of Compliance', and
- c) details of any additional national requirements, including CAA administrative procedures.

Details of appropriate supporting administrative procedures are also included where necessary.

In publishing CAPs, the CAA satisfies the obligations placed upon it by the Transport Act 2000¹, Chapter 1 Article 2 'CAA's general duty', which in paragraph 2(a) requires the CAA to exercise its functions under the Act in the manner it thinks best calculated, to further the interests of operators and owners of aircraft, owners and managers of aerodromes, persons travelling in aircraft and persons with rights in property carried in them. The only interests to be considered under subsection (2)(a) are interests regarding the range, availability, continuity, cost and quality of air traffic services.

Publication of CAPs additionally satisfies the requirements set out by the Civil Aviation Authority (Chicago Convention) Directions 2007² to ensure that it acts consistently with the obligations placed on the UK under the Chicago Convention. The CAA is obliged to consider whether it is necessary to amend United Kingdom aviation legislation to ensure appropriate implementation of an ICAO provision.

Where (a) the CAA considers it inappropriate to transpose an ICAO provision into domestic legislation and (b) the CAA has discretionary power to enforce the requirements of such a provision through a certificate, licence, or other means of approval, the Civil Aviation Authority (Chicago Convention) Directions 2007 obliges the CAA to develop and publish such requirements as are necessary to implement the ICAO provision and shall ensure that it is able to verify adherence to those requirements.

CAPs are subject to periodic revision to take account of changes to source regulatory material, feedback from industry, and recognised best practice.

¹<http://www.legislation.gov.uk/ukpga/2000/38/contents> or <http://www.legislation.gov.uk/ukpga/2000/38/data.pdf>

²[https://webarchive.nationalarchives.gov.uk/20100422174722/http://www.caa.co.uk/docs/286/CAA\(ChicagoConvention\)Directions2007\(asamended\).pdf](https://webarchive.nationalarchives.gov.uk/20100422174722/http://www.caa.co.uk/docs/286/CAA(ChicagoConvention)Directions2007(asamended).pdf)

CAP 1428 provides applicable guidance relating to the impacts of space weather to the aviation industry and is to be read in conjunction with the regulatory material referenced in the Scope section of this document. ***Non-inclusion of source regulatory material within this CAP does not preclude the end user from either the need to be aware of, or the need to comply with, the requirements contained within the source regulatory materials unless otherwise exempted from those requirements.***

It is the policy of the UK government that, unless a Difference (from an ICAO requirement) or 'Alternative Means of Compliance' (AltMoc) (related to an EASA 'Acceptable Means of Compliance' (AMC)) has been established, compliance with relevant international (i.e. ICAO and applicable equivalents such as International Telecommunications Union) and European regulatory material is required to the extent mandated in law. Additionally, compliance with national requirements that are not addressed by international or EU regulations is also required.

The words 'must', 'shall' and 'will' indicate that compliance with applicable regulatory requirements is necessary. In the case of AMC, the word 'should' indicate that compliance is required, unless complying with an approved AltMoC.

References

The following references are provided for convenience and are not exhaustive, and in view of the timescales involved in updating a Civil Aviation Publication (CAP), may not be up to date. It is therefore advised that readers take note of all applicable Regulations and of any amendments to the Regulations listed below that are implemented after publication of this document.

- Civil Aviation Act 1982
- Transport Act 2000
- The Civil Aviation Authority (Air Navigation) Directions 2001
- UK Air Navigation Order. www.caa.co.uk/CAP393
- [Statutory Instrument Air Navigation \(Cosmic Radiation: Protection of Air Crew and Space Crew and Consequential Amendments\) Order 2019](#)
- The Civil Aviation Authority (Chicago Convention) Directions 2007
- CAP 493 Manual of Air Traffic Services Part 1
- ICAO Annex 3 – Meteorological Service for International Air Navigation
- ICAO Annex 6 – Operation of Aircraft
- ICAO Annex 8 – Airworthiness of Aircraft
- ICAO Annex 11 – Air Traffic Services
- ICAO Procedures for Air Navigation Services – Air Traffic Management (Doc 4444, PANS-ATM)
- ICAO ATM Operational Contingency Plan – North Atlantic Region (Doc 006)
- ICAO Manual on Space Weather Information in Support of International Air Navigation (Doc 10100)
- ICAO Manual of Aeronautical Meteorological Practice (Doc 8896) to provide guidance on the provision and use of space weather information.
- ICAO Safety Management Manual (SMM) (Doc 9859)

- ICAO International Airways Volcano Watch Operations Group - Space Weather Information:
<http://www.icao.int/safety/meteorology/iavwopsg/Space%20Weather/Forms/AllItems.aspx>
- ICAO Circular 126 Guidance Material on Supersonic Aircraft Operations
- Single European Sky (SES) Framework Regulation (EC) No. 549/2004
- EU Regulation 2018/1139 – The Basic Regulation
- IR (EU) 923/2012 Standardised European Rules of the Air (SERA)
- IR (EU) No. 2017/373 laying down common requirements for providers of air traffic management/air navigation services and their oversight
- EASA (2012) Single event effects (SEE) on aircraft systems caused by cosmic rays, SIB 2012-10. <http://ad.easa.europa.eu/ad/2012-10>
- COMMISSION REGULATION (EC) No 859/2008 of 20 August 2008 amending Council Regulation (EEC) No 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by aeroplane (see OPS 1.390)
- EC (1996), Ionizing Radiation, Directive 96/29/Euratom, Official Journal of the European Communities 39, L159. 29 June 1996.
<https://osha.europa.eu/en/legislation/directives/73>
- EU (2013), Protection against ionizing radiation, Directive 2013/59/Euratom.
<https://ec.europa.eu/energy/sites/ener/files/documents/CELEX-32013L0059-EN-TXT.pdf>
- [European Commission. Radiation Protection No 173. Comparison of codes assessing radiation exposure of aircraft crew due to galactic cosmic radiation. 2012.](#)
- EASA (2012), Effects of space weather on aviation, SIB 2012-09.
<http://ad.easa.europa.eu/ad/2012-09>

Glossary of definitions

1. In CAP1428, where a term is used, which is defined by ICAO in a relevant Annex or PANS document, that definition will apply unless:
 - the contrary is indicated; or
 - there is a different definition in the Air Navigation Order or European Regulations.
2. The terms in the table below have been listed for convenience or have been defined to avoid ambiguity or misunderstanding, or to provide definition of words or phrases which have specific meanings within this document. In some cases, they may be slight modifications of definitions in other documents.

Term	Definition
Air Traffic Services Unit	A generic term meaning variously, air traffic control unit, flight information centre or air traffic services reporting office
Carrington event	The largest solar storm on record. It took place from 1-3 September 1859 and is named after British astronomer Richard Carrington.
Coronal Mass Ejection (Solar Flare)	An ejection of material from the sun into interplanetary space. If the material is directed towards the Earth the event may result in a geomagnetic storm.
Geomagnetic Storm	A temporary disturbance in the Earth's magnetic field caused by interaction with the solar wind and coronal mass ejection which interferes with the Earth's magnetic field
HF Comms	Communication systems relying on the use of high frequency (HF) radio waves
Ionosphere	The region of the Earth's atmosphere exposed to ionising radiation. It ranges from around 60km to 1000km in altitude
L1 Langrangian point	The point where the gravitational forces of the Sun and Earth balance
Millirem (mrem)	A rem is a large dose of radiation, so the millirem (mrem), which is one thousandth of a rem, is often used for the commonly encountered doses
Millisievert (mSv)	A sievert is a very large unit of dose so often millisieverts (mSv) or microsieverts (µSv) are used.
Moderate (<i>as used in ICAO Space Weather Advisories</i>)	Guidance on the definition of "Moderate" as used in ICAO Space Weather advisories is provided in the Manual on Space Weather Information in Support of International Air Navigation (Doc 10100).

Term	Definition
NOTAM	A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.
Radio Blackout	During a large space weather event the ionosphere may absorb high frequency radio waves instead of reflecting them. This causes problems with communication systems
Severe (<i>as used in ICAO Space Weather Advisories</i>)	Guidance on the definition of "Severe" as used in ICAO Space Weather advisories is provided in the Manual on Space Weather Information in Support of International Air Navigation (Doc 10100).
Sievert (Sv)	The sievert (Sv) is the SI derived unit of radiation dose. Quantities that are measured in sieverts are designed to represent the stochastic biological effects of ionising radiations.
Solar Cycle	The 11-year periodic change in the sun's activity including changes in the levels of radiation and solar wind emitted
Solar Flare	A brief powerful eruption of particles and intense electromagnetic radiation from the Sun's surface
Solar Radiation Storm	Interactions between charged particles (predominantly protons and electrons) and the Earth's magnetic field. The charged particles originate from the sun following a solar flare or coronal mass ejection, and travel at 1/3 the speed of light
Solar Wind	The outward flow of charged particles (primarily electrons and protons) from the sun
Space Weather	Describes conditions in space that can have an effect on earth
Space Weather Advisory	An advisory issued by an ICAO Space Weather Centre providing information regarding the extent, severity and duration of space weather phenomena that have a potential impact on high frequency (HF) radio communications; communications via satellite; GNSS-based navigation and surveillance; and radiation exposure at flight levels
Space Weather Centre	A centre designated by ICAO to monitor and provide advisory information on space weather phenomena expected to affect high-frequency radio communications, communications via satellite, GNSS-based navigation and surveillance systems and/or pose a radiation risk to aircraft occupants. <i>Note: A space weather centre is designated as global and/or regional.</i>

Abbreviations

Abbreviations	
ATS	Air Traffic Services
CME	Coronal mass ejection (Solar Flares)
ESA	European Space Agency
HF Comms	High Frequency communications
MOSWOC	Met Office Space Weather Operations Centre
mrem	Millirem
mSv	Millisievert
NOAA	National Oceanic and Atmospheric Administration
SWPC	Space Weather Prediction Centre (NOAA)
SWX	Space Weather
SWXC	Space Weather Centre
UKSA	UK Space Agency

Chapter 1

Introduction

The Earth is constantly subjected to electromagnetic and high energy particle radiation from both galactic sources and the Sun. Most of the variability is of solar origin and is collectively known as space weather. Like terrestrial weather, minor events are more common than major events and space weather impacts are managed routinely by relevant industries such as the communications industry. But generally, the day-to-day variation in space weather has a negligible impact to users of technology or to humans generally. However, on average several times in each solar cycle of 11 years space weather can have an operational impact.

During the most extreme events, associated with rare solar superstorms (and not necessarily related to the solar cycle), there are a number of issues that the aviation industry should consider because the impact will be global and significant. Although extremely rare (1 in 100-200 years) the potential disruption caused by extreme space weather cannot be ignored and it was for this reason that these were placed on the UK National Risk Register (NRR) in 2015 [latest version Cabinet Office, NRR 2017] requiring that mitigation be considered. Without appropriate preparedness an extreme space weather event could create large scale disruption of the aviation industry from which it would take weeks to fully recover.

Chapter 2

Scope

The purpose of this guidance is to inform all UK aviation sectors of the phenomena and potential impacts of space weather.

Originally the CAA published Information Notice IN–2013/089 [CAA, 2013] which informed the UK aviation industry of the potential impacts of space weather. IN 2013/89 reminded UK aviation sectors that they should consider how they may be affected by Space Weather and that they should ensure that they have appropriate procedures in place in the event of an incident. It recommended that staff should be made aware of potential effects and mitigating actions. Aircraft operators were reminded of their legal responsibility under the Air Navigation Order to protect air crew from exposure to cosmic radiation ([Statutory Instrument Air Navigation \(Cosmic Radiation: Protection of Air Crew and Space Crew and Consequential Amendments\) Order 2019, issued July 2019, refers](#)).

This document replaces IN 2013/089 following the publication of several reports and studies including those published by the Royal Academy of Engineering [Cannon et al., 2013a, b] which have highlighted the continuing need to be vigilant with regard to the effects of space weather.

Chapter 3

What is space weather?

According to the US National Space Weather Program, the term Space Weather refers to “the conditions of the sun and in the solar wind magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health” Short term variations in space weather originate on the Sun.

The Sun’s visible output is fairly constant but the total energy output changes over time due to variations in non-visible electromagnetic radiation, variations in the flow of magnetised plasma and eruptions of high energy particles. Space weather exhibits a climatology which varies over timescales ranging from days (i.e. diurnal variations resulting from the rotation of the Earth) to the 11-year solar cycle and longer. Superimposed on this climatology are weather-like variations; with space weather more dynamic on some days than others. Minor space weather is relatively common, whereas severe events due to solar superstorms are rare, occurring once every century or two.

Although there is some influence from outside the solar system, most space weather starts at the Sun which exhibits considerable variability during storm periods at radio, extreme ultra-violet (EUV) and X-ray wavelengths – these electromagnetic radiation effects are associated with flares. During storm periods, the Sun is also more likely to generate high-energy solar energetic particles (SEPs) which travel from the Sun to the Earth at relativistic speeds and depending on the source location on the Sun can take as little as 10-15 minutes to arrive. These have the potential to affect avionics and increase the crew and passenger radiation doses. Finally, the solar wind plasma speed and density, forming part of the solar corona, may increase substantially. Coronal mass ejections (CMEs), explosive injections of magnetised plasma into the solar wind, are one important manifestation of the latter and have important impacts because the associated energy is significant. CME’s can trigger geomagnetic storms in our magnetosphere (the region surrounding our planet where the geomagnetic field dominates) with important consequences for the electricity grid and indirect consequences for air navigation and communications systems.

Space weather forecasts can provide a probabilistic estimate of its likelihood, severity and impact a few hours to a few days in advance.

During minor space weather events impacts can be experienced at all latitudes but are likely to be more intense at high and equatorial latitudes. During stronger events more intense impacts may also be experienced at mid-latitudes.

Very rarely (currently estimated to be between 1 in 100 or 200 years) severe space weather occurs. Severe space weather has the potential to significantly disrupt the air