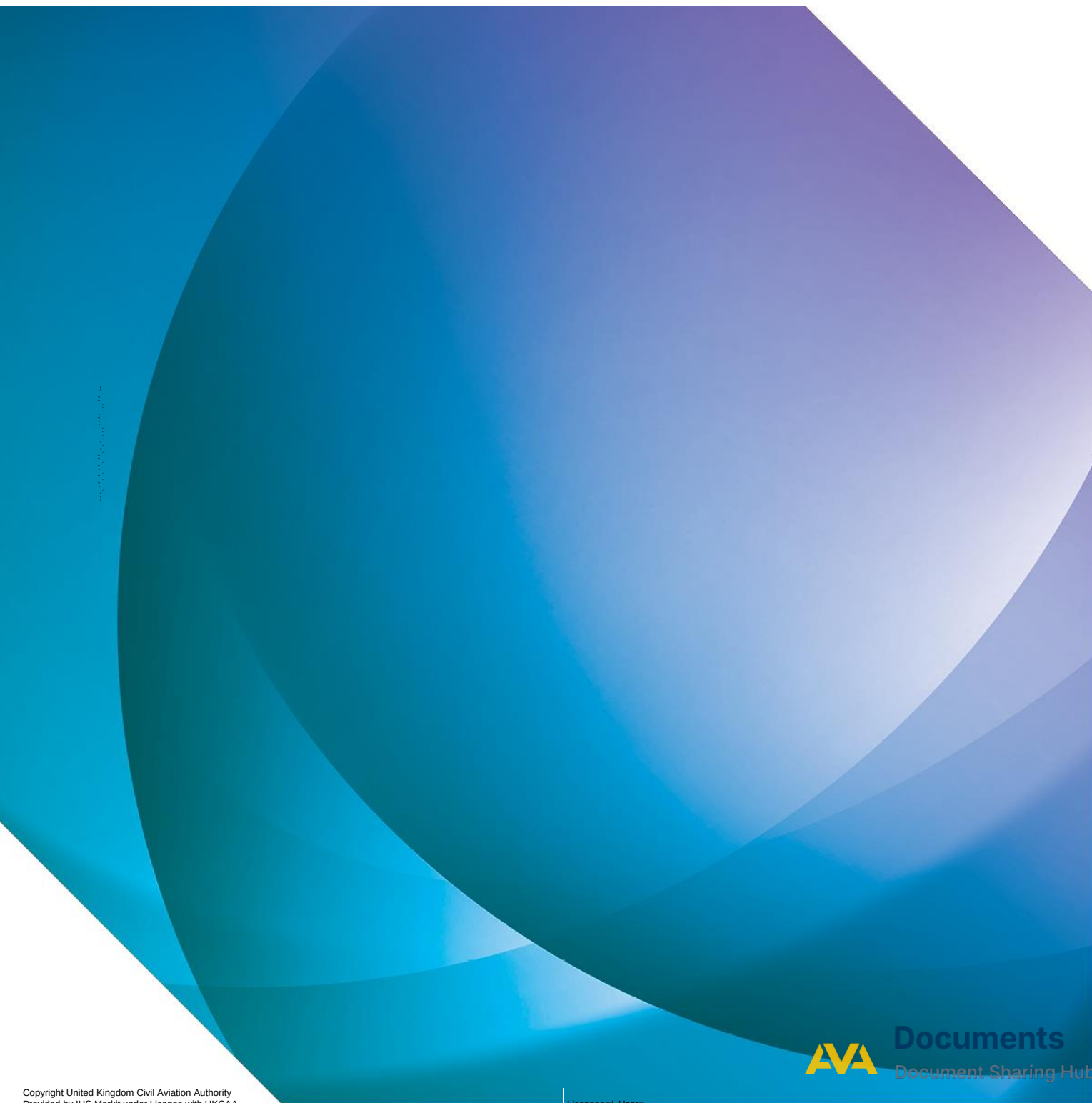


Impacts of space weather on aviation

CAP 1428



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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. Generally the day-to-day variation in space weather has a negligible impact on technology and humans but on average several times in each solar cycle of 11 years space weather can have 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 have been placed on the UK National Risk Register [Cabinet Office, 2015] 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 sectors of aviation 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 sectors of aviation 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.

This document replaces IN 2013/089 following the publication of a number of 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; on some days space weather is more severe than on others. Minor solar storms are relatively common events; in contrast, extremely large events (superstorms) occur very occasionally – perhaps 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 taking perhaps 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.

Very rarely (currently estimated to be between 1 in 100 or 200 years) a solar superstorm can occur; these have the potential for significant disruption of the air transport system. It is not possible to deterministically predict when the next event will occur, even only days ahead of the event.

The largest recorded solar superstorm is known as the Carrington Event which occurred in 1859. It was associated with a large solar flare and the associated CME took only 17.6 hours to travel from the Sun to the Earth. It caused aurora in many parts of the world where they are not normally seen –even in Hawaii. One consequence of this solar superstorm was that telegraph systems across the world misbehaved with operators able to receive messages despite having disconnected their power supplies.

During minor space weather events most of the impact is felt at high and equatorial latitudes, but during major events the impacts spread to mid-latitudes. During extreme events the effects are felt globally.

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Chapter 4

Probability of occurrence

Introduction

The following is a subjective assessment of the likely effects of space weather ranging from routine variations which occur every few days, through significant events which occur around ten times in each solar cycle, to the solar superstorm which occurs only once per century (or two). The quoted probabilities have been adapted from the scientific literature and mapped onto this subjective categorisation.

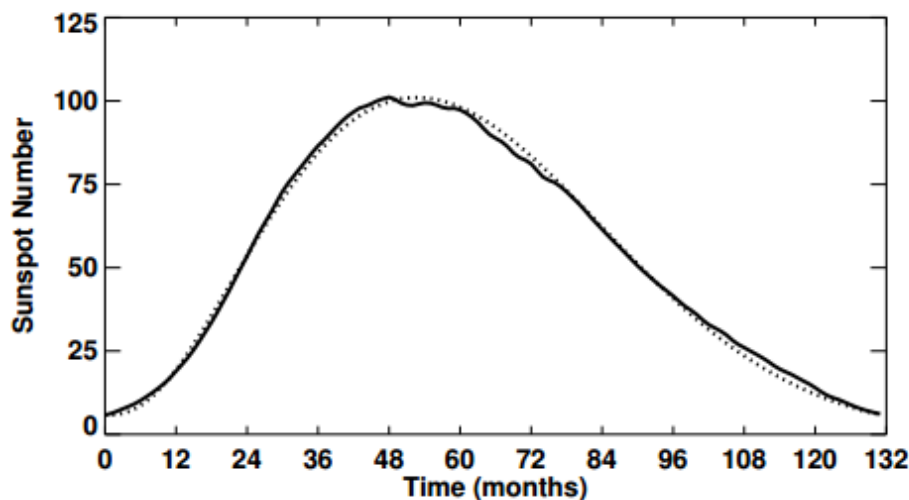


Figure 1: Average solar cycle [Hathaway 2010]

The Sun has an approximate 11 year cycle which is defined by the number of sunspots on the visible face of the Sun. It begins at solar minimum, with periods of very few, or no, visible sunspots, rising to solar maximum between 3 and 5 years after solar minimum, when there is a maximum in visible sunspots followed by a slow decline over the next 6 or 7 years back to solar minimum. Figure 1 shows the evolution in time of the 'average' solar cycle. Space weather therefore tends to occur more frequently in the 8 or so years straddling solar maximum, although significant events have occurred near solar minimum.