The likelihood
Although passengers and crew in flight during an extreme solar radiation event would receive an additional dose of radiation the increase cancer risk from one of these events is only 0.1%.

There are very few high latitude flights made from the UK as these routes are typically made between the east and west coast of North America.

How forecasting can help
Advance notice of space weather events is critical to rerouting of high latitude flights, and to alert aircraft in flight of possible loss of communications.

Marine

The impact – disruption to critical navigation systems

A number of maritime navigation and information systems use GNSS (or GPS) for positioning and timing. Trials by the General Lighthouse Authorities in 2008 and 2009 into the jamming of GNSS signals concluded that these systems are vulnerable to space weather. Navigational safety becomes reliant on the ability of the ship's crew to identify that GNSS may not be accurate and utilise traditional navigation aids and radar instead. The e-LORAN system was unaffected by the GNSS jamming.

Although many leisure mariners are believed to be reliant on GNSS positioning for their navigation the General Lighthouse Authorities recommend mariners do not rely on only one source of information and use all means of navigation at their disposal.

The likelihood
Whilst severe events leading to total failure of GNSS are rare, relatively common space weather events can still have minor disruptions on navigation systems, which can still be significant to an industry where navigation is at the centre of its operations

How forecasting can help
Mariners can benefit from space weather forecasts to advise of potential degradation or failures in the GNSS service.

Transport – road and rail

The impact – disruption or loss of GNSS

Many road users now rely on GNSS positioning devices to get from A to B but these are likely to be in error or fail completely during a significant space weather event.

Whilst inconvenient, compliance with the Highway Code and use of traditional maps should help road users avoid significant impacts to their journey.

The likelihood
Again, the threat of total GNSS failure is rare, but even relatively common moderate space weather events could disrupt the systems.

How forecasting can help
An understanding from a space weather forecast will help road users understand when their GNSS may be unreliable.

GNSS is also relied upon within the rail network, and whilst robust back up procedures are in place, network operators need to understand the level of degradation on their systems.

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Space Weather impacts

Low level space weather events occur on a regular basis and whilst they can be of concern for specific industries, in the majority of instances they have little impact on our daily lives.

Thankfully, severe space weather events are very rare, however when they do occur the impacts to our national infrastructure are extremely significant. So much so that the Government listed severe space weather events as one of the highest priority natural hazards in the **UK National Risk Register**

Main impacts at a glance.
The major impacts can roughly be divided into two areas – impacts on technology and threats to equipment and health in space and high altitude

- Power grid outages
- Disruption to GNSS/GPS systems
- HF radio comms outages
- Satellite damage
- Increased radiation threat at high altitude

Why are we concerned now?
Space weather events have always occurred, but as the biggest impacts are arguably on technology driven systems, it is only in modern times that we have been susceptible to the threat.

Different systems across the globe are exposed to varying levels of risk depending on their technical design, location and the type of space weather they are susceptible to. Our challenge is to ensure new systems are designed with appropriate engineering solutions to minimize the risk posed by space weather.

Industries and infrastructures most at risk
Whilst certain impacts (such as degradation of Global Navigation Satellite Systems (GNSS)) could affect us all, there are specific industries that are more exposed to the treat of space weather. The Met Office has been working closely with these industries to identify the threat, the extent of the impacts and to understand how forecasts can help them mitigate the risk.

please visit www.metoffice.gov.uk/space-weather for more information

Energy Industry

The impact: power blackouts and damage to infrastructure
Geomagnetic storms can cause rapid variations in the Earth's magnetic field which, in turn, induce an electric field in the Earth's surface. This electric field induces electrical currents in long conductors like power lines causing voltage instability and transformers to burn out.

The most recent experiences of space weather impacts have included power blackouts in Quebec, Canada, 1989 and Malmo, Sweden, 2003. These blackouts were the result of voltage instability in their power grids which collapsed in seconds leaving large areas without power for many hours.

The likelihood

Whilst still a significant threat, the UK is at less risk from geomagnetic storms because it is further south from the geomagnetic North Pole than Canada and Scandinavia. As a relatively small country, our electricity transmission lines are shorter which means the extent to which impacts can be induced in our equipment is reduced. The electricity transmission system is also more highly connected than many other countries and has a great deal of built in redundancy, which allows the induced impacts to disperse more easily.

Oil and gas pipelines can also act as long conductors so are affected by the same electrical currents. To minimise corrosion pipelines are coated and fitted with corrosion protection devices but these are compromised by geomagnetic storms reducing the overall lifetime of the pipeline.

How forecasting can help

Energy companies can use space weather services to help minimise the impact of geomagnetic storms, improve the design and modelling of future, more resilient, systems and increased monitoring of impacted systems.

Satellite Industry

The impact – damage to satellites and impacts on performance

For most of the time the Earth's magnetosphere shields satellites from the high energy radiation in space. During significant space weather events this shielding breaks down and geostationary satellites can become exposed and prone to damage.

Electrostatic build up on and within the satellites can cause errors and component damage when it discharges. Solar energetic particles can degrade the satellite's solar panels reducing the life expectancy of the satellite; surface charging can damage the electronics and can also produce single event upset, which in turn cause errors within the computer systems.

The likelihood

Forty seven satellites suffered temporary outages during the geomagnetic storm in Oct 2003 and two were damaged in 2012. Given the range of spacecraft in operation today the Royal Academy of Engineering estimated 10% of the satellite fleet might suffer from a temporary outage during an extreme event.

Global Navigation Satellite Systems (GNSS) often known as Global Positioning Satellites (GPS) would also be impacted making such systems inoperable for a number of days. This will cause operational impacts to industries such as aviation and shipping (see below) but could also impact those which rely on GNSS for critical timing information. Holdover clocks are available to maintain systems reliant on high precision timing for a few days.

An extreme geomagnetic storm will also result in an expansion of the Earth's atmosphere which disrupts the orbit of satellites in a low Earth orbit degrading predictions of their position. It can take several days to reacquire positioning data and regain communication with the satellite.

How forecasting can help

Satellite operators can use space weather forecasts to advise of potential degradation or failures in the services they provide.

Communications

The impact – radio blackouts and loss of long distance communication

Much or our long distance communications relies on the state of a layer in the atmosphere called the ionosphere. HF communications are bounced off the ionosphere to travel beyond line of sight and spacecraft operators communicate with their satellites at VHF, UFH and higher frequencies, which pass through the ionosphere.

During solar flares the intense burst of radiation interferes with the ionosphere, absorbing HF communications signals and causing radio blackouts on the sun-lit side of the Earth.

During geomagnetic and solar radiation storms the ionosphere is modified, making it difficult for VHF etc to pass through so communications signals may be degraded in or near the Polar Regions. As a result mobile satellite communications are of very poor quality or may also be completely unavailable. This impact is at its strongest around dusk and dawn.

The likelihood

The Royal Academy of Engineering report {Link to http://www.raeng.org.uk/publications/reports?q=space%20weather} concluded that whilst still a threat, the UK terrestrial mobile communications networks are more resilient to space weather than elsewhere in the world, including the US, because they do not rely on GNSS timing.

How forecasting can help

Solar flares travel at the speed of light so there is no method of forecasting the resulting radio blackouts. However advanced notice of heightened solar activity can help to flag the risk that blackouts could occur.

Aviation

The impact - Loss of HF comms - unable to use high latitude routes, additional radiation doses at high altitude.

Thousands of flights every year are made more cost effective by using high latitude polar routes. Communication on these routes is only possible by using HF (High Frequency) comms, so space weather which causes radio blackouts at these frequencies whether due to solar flares or increased solar radiation levels, can have a significant impact. Aircraft in flight would follow well established procedures for such a loss of communications but those yet to take off may be diverted to lower latitudes routes which may longer and result is disruption to flight schedules. Passengers and crew on certain routes may be exposed to increased radiation levels during solar radiation storms.