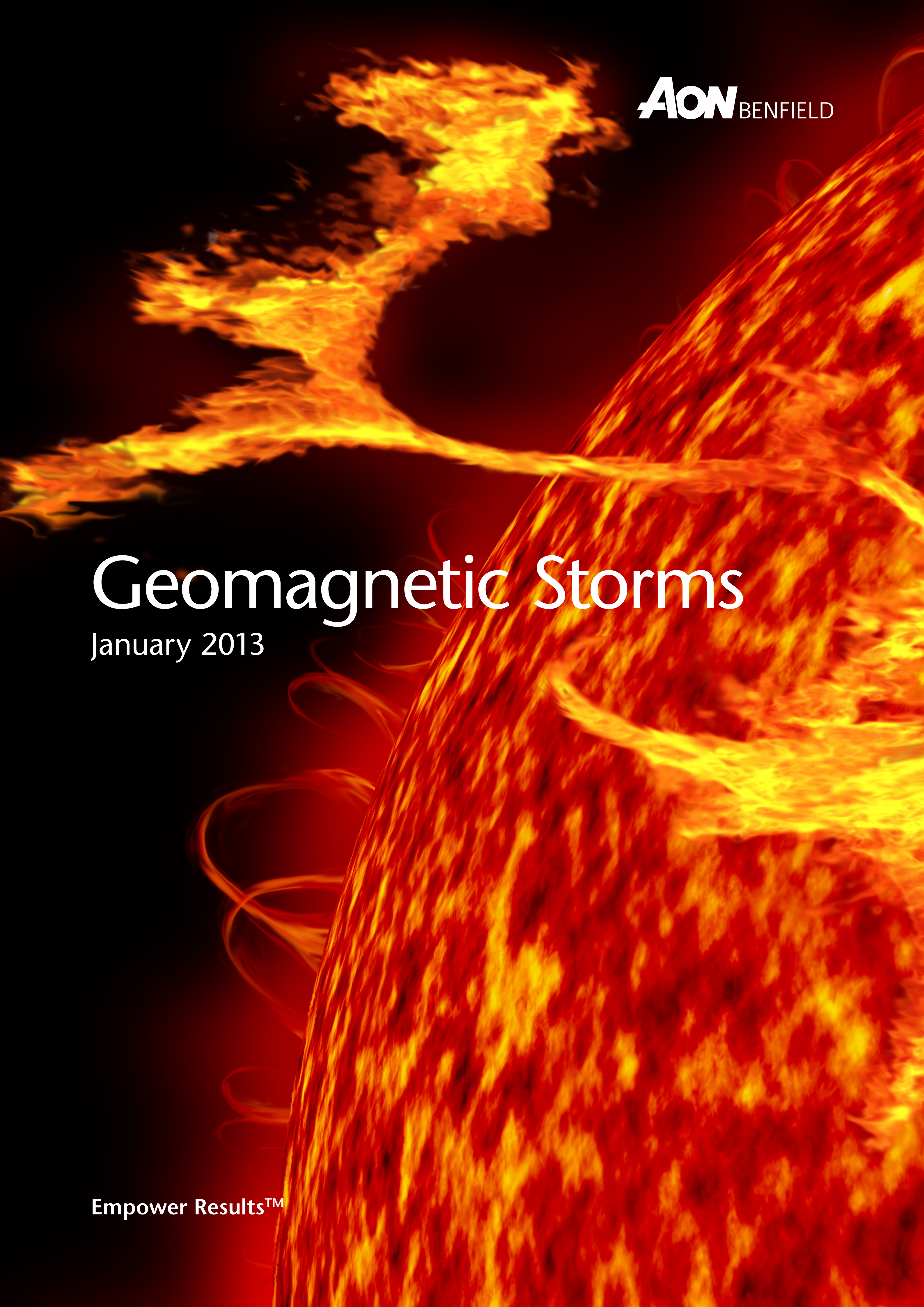


AON BENFIELD

Geomagnetic Storms

January 2013

Empower Results™

Contents

Pear-Shaped Phenomena

Aon Benfield uses "Pear-shaped phenomena" to refer to relatively low probability high consequence events that pose substantial risks to industry and the economy. Such events have also been called wild cards, future shocks, dirty grey swans and even black elephants. Unlike black swan events which are defined as "unforeseeable" pear-shaped phenomena (PSP) can be anticipated. With careful research and communication, the insurance industry can be at the forefront of risk mitigation for PSP including geomagnetic storms and extreme solar weather.

Cover image: Solar flares on the surface of the sun. The diameter of each flare is several times the diameter of the Earth. (Source: Shutterstock)

Executive Summary

Geomagnetic storms and extreme solar weather are a realistic threat to the world's electrical power grids, telecommunication systems and global satellite navigation networks. Re/insurance industry awareness of geomagnetic storms has grown in recent times, but accurate assessment of risk still remains in its infancy for all but a few niche sectors. The rapid emergence of technology and business dependencies means that mainstream re/insurance professionals are unlikely to be able to accurately price this risk, offer coverage or issue exclusions. Further, supply chain disruption mitigation measures, contingent business interruption policies and enterprise risk management strategies rarely cater adequately for the scenarios that can arise out of extreme space weather.

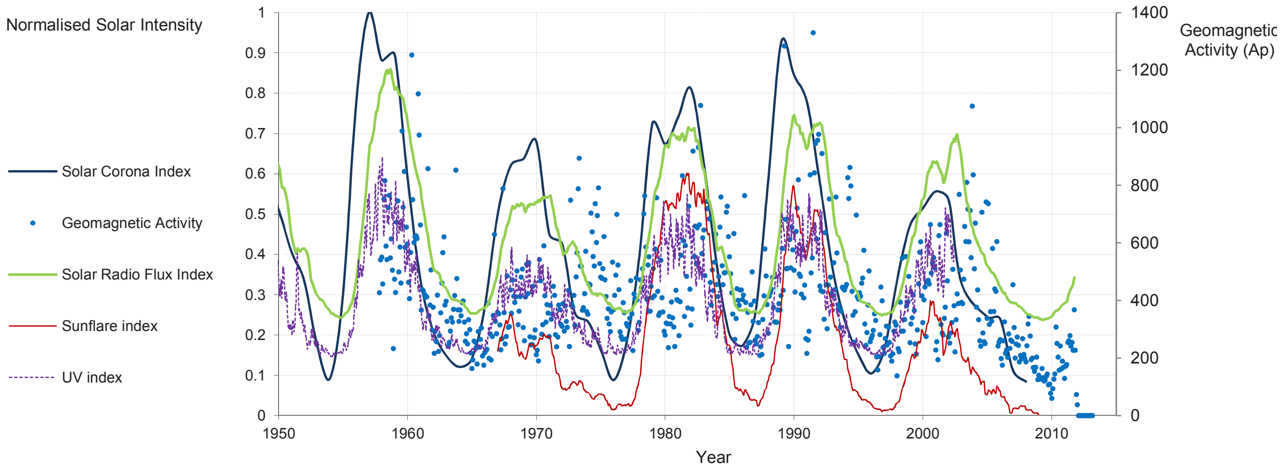
Threat Assessment

Solar activity follows a roughly 11-year cycle. The next maximum in solar activity is expected to occur in late 2012 or early 2013 (see Figure 1). This is based on observations of sunspot activity and other metrics of solar activity, and points to an increase in the number of solar flares and the ejection of significant amounts of radiation from the Sun (known as coronal mass ejections).

There is no single cause and effect for how extreme solar events impact Earth's systems. However, three areas of modern critical infrastructure are especially vulnerable:

- **Electrical Power Distribution:** Massive ground currents resulting from geomagnetic storms can flow through electricity distribution networks, resulting in large scale blackouts and permanent damage to transformers. Modern high voltage power grids are more vulnerable to space weather impact that ever before (Kappenman, 2010).
- **Telecommunications:** Enhanced X-ray and extreme ultraviolet solar radiation during a solar flare causes a marked increase in ionisation of the ionosphere, with implications for radio propagation and telecommunications systems, including blocking of global communications.
- **Global Satellite Navigation:** Solar radiation trapped in belts around Earth interacts with satellites leading to orbit decay, static electrical discharges and disabling of GPS services with particular consequences for aviation in high latitudes.

Figure 1: Observed Metrics of Solar and Geomagnetic Activity



Source: Aon Benfield

Historic Events

October-November 2003

At least seven satellites produced electronic errors, three experienced solar array degradation and one had a change in orbit dynamics. Aviation communications were disrupted for 18 days from the 19th of October.

Aircraft routes north and south of 35° latitude produced excessive radiation exposures for passengers and crew. Railway (electronic) signalling problems in Russia. Significant cumulative damage to transformers and to the electrical grid in South Africa.

14 July 2001

International Space Station experienced a 15km decrease in altitude.

March 1989

The most severe space weather event since the space age began in 1958, produced a footprint across about 120 degrees of longitude and 5-10 degrees latitudinal spread. Permanent damage to several major transformers. An electric power blackout in Quebec lasted 12 hours and affected five million people. The eventual cost was estimated at >USD2 billion.

About 200 significant anomalies occurred in power grids across the American continent. Damage to large transformers also occurred in New Jersey and in the U.K.; power interruptions were experienced as far south as California. Cumulative transformer damage which induced failure in subsequent space weather events has been suggested. The first fibre optic voice cable was nearly rendered inoperative by the large potential difference between New Jersey and England. Problems with pipeline protection systems in Scotland. Swings in steered North Sea drill heads of up to 12 degrees.

May 1921

Magnetic field changes of up to ~5000nT/min (cf. March 1989 storm, ~480nT/min over Quebec). Induced currents caused fires in telegraph equipment in Sweden.

September 1859

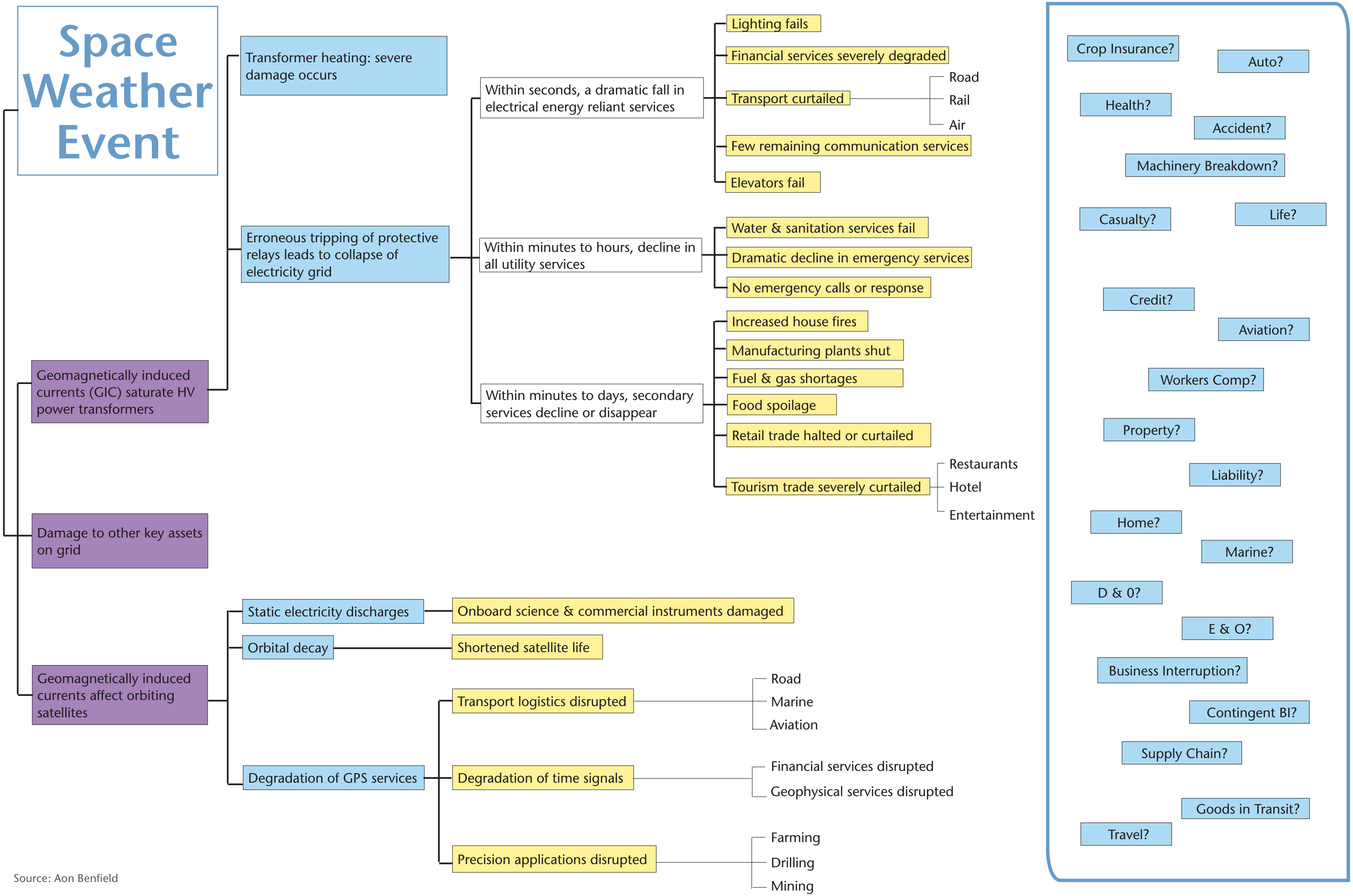
The so-called Carrington event, the most severe space weather event in the last 150 years. The brilliancy of the solar flare was fully equal to that of direct sunlight. Auroras occurred globally with red glows visible to within 23 degrees of the geomagnetic equator in both northern and southern hemisphere. In the United States and Europe fires were started by arcing from currents induced in telegraph wires.

Polar ice core studies suggest this was the most severe space weather event in the last 450+ years.

Repeat of the 1921 space weather event

Figure 2 illustrates the chain of possible consequences resulting from a moderately large solar flare (equivalent, say, to the 1921 event) directed at Earth. Highly correlated multipoint failures could be spread over a geographic area larger than a single continent.

Figure 2: Some Potential Consequences of a Repeat 1921 Space Weather Event



Source: Aon Benfield

Just two primary consequences are considered in Figure 2 – the saturation of high voltage power transformers by geomagnetically-induced currents (GIC), and the effects of GIC on satellites in orbit.

Collapse of parts of the electric grid as a result of surges is potentially the most serious effect of a space weather event. Power failure to a wide area – potentially tens of thousands of square kilometres – could shut down lighting, heating, all major utilities, communications and transport, emergency services and retail trade. Some effects will be felt immediately; some may take days – delayed until fuel for emergency generators can no longer be supplied. A prolonged outage of three or more days would probably lead to looting (for food if nothing else), rioting and civil commotion.

High voltage transformers which step up/down power on major supply lines are not easily replaced; few spares are available as each is purpose-built.

One report suggests global manufacturing capacity for HV transformers is only about 70 units per year. A repeat of the 1921 space weather event might damage at least several hundred such units worldwide, with replacement of many transformers taking a year or more.

GIC affect satellites with static electricity discharges damaging on-board instruments, shortening the life of satellites by orbital decay and degrading GPS services which are widely used for transport logistics. Precise time signals are also used for financial transactions, mobile phone services and, indeed, synchronization of the electric grid.

A 2007 estimate put the number of operating satellites in orbit at 936 with a combined value between USD170 and USD230 billion. Possibly a third of these are insured.

As an example of the range of potential consequences for aviation the use of GPS increases navigation accuracy, allowing reduced vertical and horizontal separation of aircraft without increased risk, enhances the ability to land aircraft in poor weather and the use of polar routes. Reduced satellite navigation signals requires moving aircraft from polar routes to sub-optimal routes, reducing cargo capacity, increasing flight times, fuel use, delays and disrupted connections. Supervisory Control and Data Acquisition systems (SCADA) and related computerised engine management systems may fail.

Estimated costs

Few attempts have been made to estimate the potential costs of space weather events.

However, a 2004 report of the US National Academy of Sciences estimated the economic costs of a repeat of the 1921 event for the US alone at USD2 trillion for the first four years but with recovery taking up to ten years (NAS, 2008). Up to 350 major transformers would be at risk with up to 130 million people left without power. Even when a spare transformer is available replacement takes several weeks.

The 1996-2005 sunspot cycle damaged around 15 satellites at a cost of about USD2 billion (Odenwald et al., 2006)

It has been suggested a repeat of the 1859 space weather event would produce a potential economic loss of USD44 billion for lost satellite transponder revenue plus about USD24 billion for the replacement of geosynchronous satellites. An 1859-calibre storm would produce satellite anomalies at about 100 times the rate produced by the most severe storm in the period 1996-2005 (Oldenwald et al., 2006).

Insurance Response

As Figure 2 implies a severe space weather event could cripple sections of the electricity grid and some satellite-based communication systems. The exact outcomes for the insurance industry are unclear but there is the potential for almost all lines of business to be severely affected. Cumulative damage during successive space weather events leading to eventual failure may prove especially problematic for the insurance industry.

Insurance policies and reinsurance treaties are likely to contain the legal triggers for liability in the event of the catastrophic failure of electricity distribution, telecommunications or satellite navigation networks. However, these contracts are unlikely to have been drafted with any degree of consideration for a loss occurrence of the type initiated by extreme solar weather.

The reasons for this are multi-dimensional:

- The absence of a defining industry-wide loss occurrence from extreme solar weather that has triggered large scale economic and social disruption and recoveries on insurance policies
- Most risk professionals lack an understanding of the technical complexities of the hazard and vulnerability of components of insured assets to geomagnetic storms
- The continued dependence of the majority of direct and contingent business interruption contracts on the loss of use of property due to physical damage
- The potentially exotic nature of recoveries, with material damage and replacement costs ultimately to be a very small component of total losses

Mainstream risk professionals and society are unlikely to price cover for extreme solar weather-induced failure of modern critical infrastructure. What risk managers and brokers can do is utilise this threat to develop broadbased contingent business interruption and extra expense products that currently require a physical damage trigger. In this way, the industry will be better prepared to deal with the 'wild card' catastrophes that will inevitably arise.

Pertinent coverage and contract issues that will affect re/insurance recovery include:

- Loss Occurrence definitions
- Territorial limitations
- Contingent Business Interruption coverage and public utilities extensions
- Business continuity plans to deal with catastrophic failure of modern critical infrastructure
- Riot, civil unrest and other social responses to prolonged power and communication outages.

As business interruption policies flourish and the definitions of loss occurrence broaden, a larger proportion of losses from catastrophic events will be made up of losses of wages and revenue as opposed to property losses.

These changes offer growth areas for the insurance industry and opportunities for risk management professionals.

Mitigation

There is a 50/50 possibility that a severe space weather event can be forecast hours in advance allowing decoupling/shutdown of the electricity grid (though a shutdown might create other insurance issues). Many utilities maintain a spare HV transformer but there are major issues of compatibility, transportation and installation suggesting even then that returning service is a matter of weeks rather than days. Some grids now include devices to prevent entry of currents produced by space weather events.

Space radiation-induced errors in digital chips can be reduced by using hardened or triple-redundant chips. High precision local clocks can be used to minimise disruption from corrupted GPS time signals. Flying at reduced altitudes significantly decreases the error rate in digital chips controlling software systems and radiation exposure for passengers and crew, though at the expense of increased fuel use.

With adequate warning satellites can be parked in safe mode, minimising much of the potential damage. In addition there is a fairly widespread transponder overcapacity, suggesting some redundancy in the satellite communication system.

Conclusion

We are uncertain about the exact consequences of a space weather event for the insurance industry. There have been several lesser events in the last few decades with limited insurance losses. Future losses will depend on severity of the event/s, interactions with the earth's magnetosphere, the territories most affected, the lines of business covered, the precise wordings of policies and their interpretation, and the duration and extent of electricity outrages.

Each insurer needs to work carefully through the potential ramifications of a severe space weather event, especially as a peak in solar and geomagnetic activity is expected in 2013-2014.

Space weather events and possibly extreme consequences are not black swans. Space weather events and possible insurance losses are foreseeable. Insurers should anticipate them.

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Thought Leadership

Today's climate of rapidly developing technologies, global dependencies and strategic rivalries places an ever-increasing importance on our ability to learn, influence and adapt. Aon Benfield empowers considered and effective risk management and reinsurance decision making in this evolving environment, providing new insights and analyses.

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